Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

ATLAS
OF
AMERICAN AGRICULTURE

PHYSICAL BASIS
INCLUDING
LAND RELIEF, CLIMATE, SOILS
AND
NATURAL VEGETATION

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF INFORMATION
WASHINGTON

PUBLICATIONS
PRESS SERVICE
RADIO SERVICE

NOTICE

The accompanying copy of the ATLAS OF AMERICAN AGRICULTURE is furnished for official use and becomes the property of the office, division, station, laboratory, or bureau, and not of any individual.

If a personal copy is desired it may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. for $17.00.

M. C. Merrill,
Chief of Publications.

AD-33 Bookplate (1-63)

NATIONAL AGRICULTURAL LIBRARY

UNITED STATES DEPARTMENT OF AGRICULTURE 1862 1889

The Section, Frost and the Growing Season, is incorrectly paged. The section is complete as here bound--one introductory sheet followed by 12 pages.

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

ATLAS
OF
AMERICAN AGRICULTURE

PHYSICAL BASIS
INCLUDING
LAND RELIEF, CLIMATE, SOILS, AND NATURAL VEGETATION OF THE UNITED STATES

PREPARED UNDER THE SUPERVISION OF
O. E. BAKER
BUREAU OF AGRICULTURAL ECONOMICS

CONTRIBUTIONS FROM THE WEATHER BUREAU, WILLIS R. GREGG, CHIEF; BUREAU OF CHEMISTRY AND SOILS, H. G. KNIGHT, CHIEF; BUREAU OF PLANT INDUSTRY, FREDERICK D. RICHEY, CHIEF; FOREST SERVICE, F. A. SILCOX, CHIEF; BUREAU OF AGRICULTURAL ECONOMICS, A. G. BLACK, CHIEF

U. S. DEPT. OF AGRICULTURE
NATIONAL AGRICULTURAL LIBRARY
FEB 11 1972
CATALOGING - PREP.

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1936

INTRODUCTION

Physical conditions have been the principal influences directing agricultural development in the modern world. Temperature and moisture, soil, and land relief or lay of the land or topography—all have played their parts. In general, the protection of life and property, so essential to agricultural development throughout the history of the world, has been better maintained during the last century than during previous periods, so that the results of natural forces have been constantly more evident. Population has continued to increase, although recently at a lessening rate, thus pressing upon the natural resources, and urging upon mankind the necessity for understanding the underlying factors that condition our agricultural life.

The influence of the physical conditions may be altered, but this alteration is expensive in terms of capital or labor or both. These physical conditions yield under the pressure of man's technic, but soon the resistance reaches the point where additional pressure becomes unprofitable and sometimes futile.

Progress in civilization does not diminish man's dependence upon nature. Instead, each advance in transportation facilities, in the technic of production, and in economic organization makes agriculture increasingly responsive to the conditions of temperature, moisture, topography, and soil. The control of the physical conditions over agricultural development, instead of being mitigated by the progress of science and invention, has been intensified and enforced. The commercialization of agriculture and the keen competition resulting between different regions make the production of a crop sensitive even to the more minute geographic advantages or disadvantages of a district, and compel shifts in crop production or in use of the land to be made with an alacrity unknown in self-sufficing systems of farming.

In the United States, with its almost continental extent of area within which the forces of competition could operate unfettered by tariff or other restrictions, and with new lands being constantly brought into competition with old lands, the influence of the physical conditions upon agricultural development has been extraordinarily powerful.

For example, the invention and extensive use of farm machinery that has constantly become more efficient and essential to profitable crop production, has greatly increased the influence of topography in determining the utilization of land. Hilly regions, in addition to the drawback of lesser accessibility as compared with level lands, particularly in former times, and the disadvantage of generally shallower and less fertile soils, especially susceptible to erosion, now suffer from the further disadvantage of being poorly adapted to the use of modern farm machinery. Certainly in the production of cereal crops, and probably of hay, one man can farm twice the area of level land that he can of hill land; and if the level land be more fertile, as is usually the case, the handicap of the hill-land farmer is further increased.

These handicaps are sometimes counterbalanced by economic advantages of location with reference to markets, lower wages for labor, and other factors. But during the decade 1919–29, the general trend, according to the census, was strongly toward contraction of the crop area in districts of hilly surface or of poor-to-fair soils. About 1,940 counties, nearly all located in such districts, reported a decrease in crop acreage harvested. Simultaneously in 1,130 counties, located mostly in the Great Plains regions, where the tractor, the combine, and other machinery were reducing the cost of grain production, an equivalent increase in crop acreage occurred.

But should the trend of a century from self-sufficing farming toward commercial agriculture be permanently reversed, as it was reversed by the economic depression and urban unemployment beginning in 1930, the influence of the physical conditions upon agricultural development would be greatly altered. The increase of more than 500,000 in number of farms between 1930 and 1935 took place mostly in regions of hilly topography and poor soil, where the birthrate also generally was high, and around the cities. Young people, unable to find urban employment, remained on farms, and others returned to the farms from the cities. Abandoned farms were reoccupied, other farms were subdivided, fields were rented and made into farms, all without much regard to the advantages for farming, as compared with other parts of the country. The influence of the physical conditions upon agricultural development varies with the economic and social situation.

USE OF THE ATLAS

The maps and graphs contained in this Atlas will be of most value to students of agriculture, of climate, soils, and natural vegetation. The maps should also be useful to persons who are considering farming from the commercial standpoint, or are seeking a home, and wish information as to climatic, topographic, and soil conditions in any given section of the United States.

It should be noted that the maps are necessarily generalized, and that for land surface and especially for soils, large-scale maps showing detail should be consulted relative to any particular farm or tract of land. The United States Geological Survey has mapped the land relief, or topography, on a scale generally of 1 inch to the mile, over about one-half of the United States, including a large number of agricultural areas. These "quadrangle sheets" are on file in many city and university libraries, and some of them can be bought from the Director of the Geological Survey, Washington, D. C. The Soil Survey of the United States Department of Agriculture has also covered about one-half of the area of the United States, on the same scale of 1 inch to the mile. (See pl. 1, p. 8, in the Soils Section.) These county soil reports, covering 1,359 counties, contain detailed descriptions of local climatic and topographic, as well as of soil conditions. They also describe the character of the farming and are commended to anyone who is seeking information about the agriculture of a locality. These reports, with maps, are available in many libraries, or can be bought from the Superintendent of Documents, Government Printing Office, Washington, D. C.

HISTORICAL NOTE

The original plan for this Atlas included not only the sections printed in this volume, but also other sections relating to the crops, to livestock, to size of farms and systems of farming, to land utilization and farm tenancy, to rural population and organizations. Of these sections only two were published—one on *Cotton* was issued as advance sheets in 1918 and another on *Rural Population* was issued in 1919. Soon after these sections were published it was decided to confine the publication of data in atlas form to the physical conditions, which are more or less permanent, and which require presentation of the data by use of colors superposed on a black base to facilitate identification of locality. Much of the material that had been assembled relating to the crops and livestock, land utilization, and farm tenancy, was used in the preparation of a series of articles that were published in the Yearbooks of the Department of Agriculture from 1921 to 1925, inclusive. Other material has since been published in the Graphic Summary of American Agriculture.

Meanwhile the sections of the Atlas relating to the physical conditions were issued in the form of advance sheets as rapidly as the work of compilation and drafting could be completed. *Frost and the Growing Season* was issued in 1918, *Precipitation and Humidity* in 1922, *Natural Vegetation* in 1924, *Temperature, Sunshine, and Wind* in 1928, and, finally, the *Soils* section in 1935, coincident with the reprinting and publication of all these sections in the present single volume. The map of *Physical Features* was compiled and drawn in 1914 and 1915, but was never published, only 500 copies being printed and distributed from time to time to persons particularly interested.

Thus after 20 years the first part of the original plan of the Atlas is completed. Obstacles have retarded the progress of this project, but the support of successive secretaries of agriculture, directors of information, and bureau chiefs has never been lacking. Without this consistent support even these few sections would never have been finished. A governmental research agency, with its momentum, permanence of personnel, and cooperative spirit, as well as its files of information and relatively ample funds, provides a peculiarly favorable environment for such a long-time project as the preparation of this Atlas has proven to be. It is the United States Department of Agriculture, including the thousands of cooperative and other observers in the Weather Bureau, the hundreds of men who have worked on the Soil Survey, as well as the less numerous but no less essential research workers, clerks, and draftsmen in Washington, that has, in truth, prepared this Atlas.

O. E. Baker,
Senior Agricultural Economist,
Bureau of Agricultural Economics.

312639

1
Ag864At

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

ATLAS
OF
AMERICAN AGRICULTURE

LAND RELIEF

CONTRIBUTION OF THE BUREAU OF AGRICULTURAL ECONOMICS
A. G. BLACK, CHIEF

BY

F. J. MARSCHNER, *Research Assistant*

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1936

SELECTED REFERENCES

Barnes, C. P., and Marschner, F. J.
MAP OF NATURAL LAND-USE AREAS.
Scale, 1:4,000,000.
U. S. Department of Agriculture, 1933.

Bowman, Isaiah
FOREST PHYSIOGRAPHY:
Physiography of the United States and principles of soils in relation to forestry.
New York, 1911.

Brigham, Albert P.
GEOGRAPHIC INFLUENCES IN AMERICAN HISTORY.
Boston, 1903.

Fenneman, Nevin M.
PHYSIOGRAPHIC DIVISIONS OF THE UNITED STATES.
Annals of the Association of American Geographers Vol. VI.
Cambridge, Massachusetts, 1917.

Fenneman, Nevin M.
PHYSIOGRAPHY OF WESTERN UNITED STATES.
New York, 1931.

Hayden, Ferdinand Vandiveer
U. S. GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES.
Reports, bulletins, maps.
Department of the Interior, 1867–1882.

King, Clarence
U. S. GEOLOGICAL EXPLORATION OF THE FORTIETH PARALLEL.
Report, monographs, maps.
Engineer Department, U. S. Army, 1870–1880.

Lobeck, A. K.
A PHYSIOGRAPHIC DIAGRAM OF THE UNITED STATES.
Scale, 1:3,000,000.
Chicago, 1921.

Powell, John Wesley
U. S. GEOGRAPHICAL AND GEOLOGICAL SURVEY OF THE ROCKY MOUNTAIN REGION.
Reports, maps.
Department of the Interior, 1876–1880.

Salisbury, Rollin D., and Atwood, Wallace W.
THE INTERPRETATION OF TOPOGRAPHIC MAPS.
U. S. Geological Survey. Prof. Paper No. 60, 1908.

Semple, Ellen Churchill
INFLUENCE OF GEOGRAPHIC ENVIRONMENT, ON THE BASIS OF RATZEL'S SYSTEM OF ANTHROPO-GEOGRAPHY.
New York, 1911.

State geological surveys have in many cases published topographic and geological maps, and descriptive text for parts or the entire State.

U. S. Geological Survey publishes topographic quadrangle sheets and geologic folios, State maps, and United States maps on several scales. (Address the Director for index maps and list of publications.)

U. S. General Land Office has published maps of public domain States, and has on file plats of all the surveyed townships.

Wheeler, George Montague
U. S. GEOGRAPHICAL SURVEYS WEST OF THE ONE HUNDREDTH MERIDIAN.
Reports, monographs, maps.
Engineer Department, U. S. Army, 1869–1884.

Whitbeck, Ray H., and Thomas, Olive J.
THE GEOGRAPHIC FACTOR: ITS ROLE IN LIFE AND CIVILIZATION.
New York, 1932.

LAND RELIEF

Land relief, as commonly understood, comprises two elements: elevation above sea level or adjacent country, and degree and direction of slope. In its major forms of mountains and plains, and their special arrangements with regard to oceans and directions of winds, land relief determines climate over vast regions of the country. Degree of slope is likewise a major factor in determining drainage conditions which in turn affects soil stability and soil development. Land relief, climate, and soil constitute the main natural factors controlling, in innumerable combinations, the potential use of rural land for crops, grazing, and forest. The influence of one or the other of these factors often dominates, and may be strong enough to eliminate one, two, or even all rural land uses.

Of the total land area of the United States, it is estimated that on the basis of physical conditions about 29 percent can be used for crops, or pasture, or forest; about 24 percent for crops or for pasture; about 14 percent is suited only to forest with some incidental grazing; about 3 percent can be used only for forest or pasture; about 25 percent can furnish only a scanty grazing, and nearly 4 percent is waste land having no agricultural, forest, or pastural use (fig. 1). But within the regions of major rural land uses, the type of farming, of grazing, and of forest vary widely, and reflect the adjustment of human enterprises to the possibilities of the natural environment.

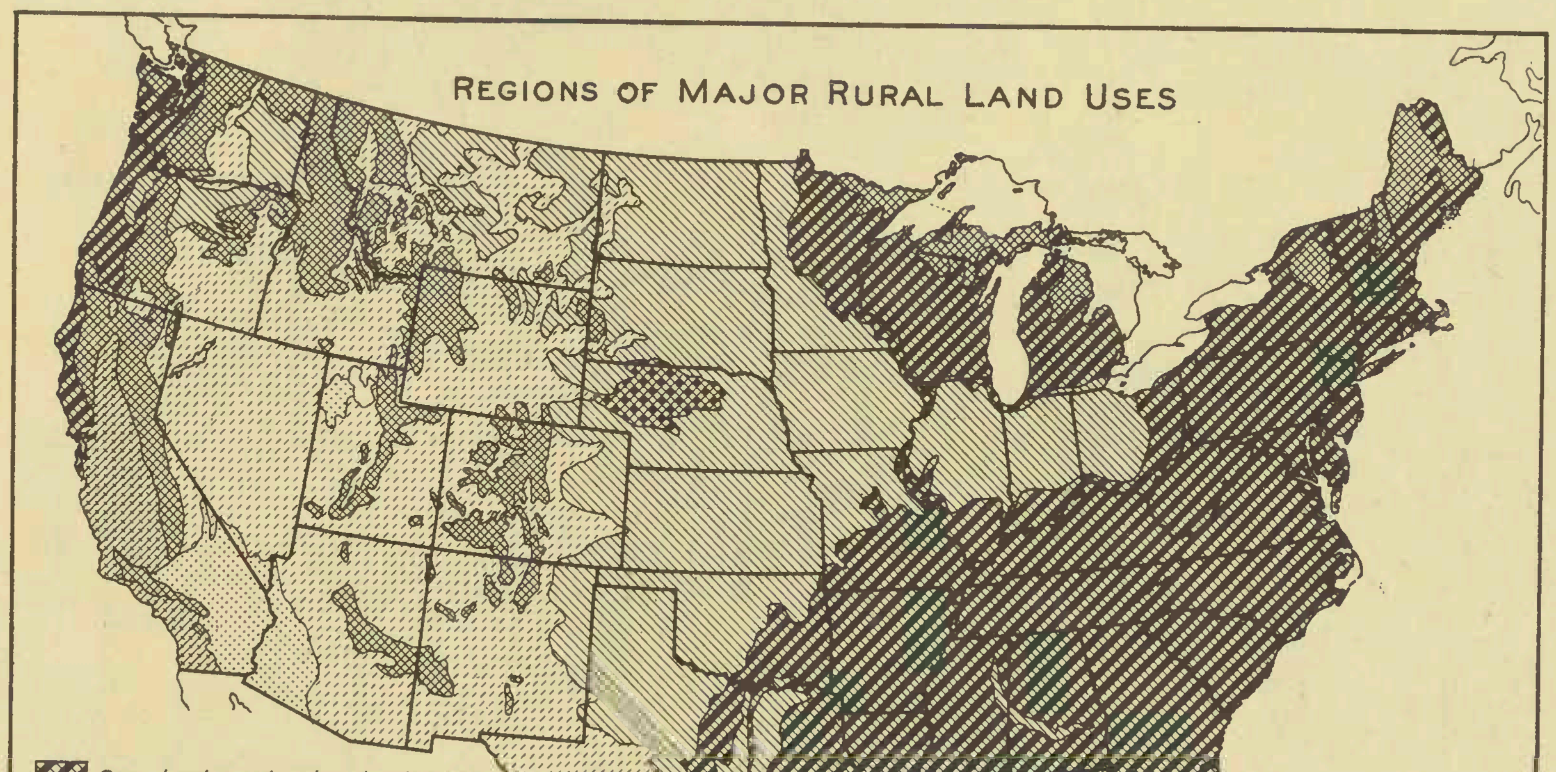


Figure 1.—The main natural vegetation types—forest, grassland, and desert shrub—are indicative of major rural land uses. In some areas, however, one or another use suggested by the natural vegetation is practically eliminated because of other factors. Forestry, for example, scarcely exists in the eastern Corn Belt, although the land was originally timber-covered, because the fertile soil and gently rolling surface relief favors crop production and pasturage. In the Sand Hills of Nebraska cultivated crops are not grown extensively because of the danger of drifting soil, and in most of the western forest areas the cultivation of crops is prevented by the rough topography.

MAJOR PHYSIOGRAPHIC FEATURES

Of all the physical factors contributory in making the natural environment such a powerful influence, land relief is the most stable. Regions and landscapes obtain from land relief their dominant scenic characteristics. Only the most salient features will be noted here, primarily to serve as background for later discussion.

The arrangement of the major physiographic divisions of the United States is unique. The interior consists of vast plains bounded on the east and west by two extensive mountain systems. On the east rise the low plateaus and ridges of the Appalachian Highlands; and on the west the Cordillera, a belt of mountain ranges, plateaus, and basins, over 1,000 miles wide in places. The trend of these two mountain systems converges toward the south. Between, at their nearest approach, is interposed an interior highland, composed of the Ozark Plateaus and Ouachita Mountains. In the north, around Lake Superior, the Interior Plains merge into the Laurentian Upland, which extends far into Canada. Along the Atlantic and the Gulf Coast, from Long Island southward into Mexico, the Appalachian Highlands and Interior Plains are bordered by a Coastal Plain. In the Cordillera three major divisions are recognized—the Rocky Mountain system on the east, the Pacific Mountain system along the Pacific Coast, and the Intermountain Plateaus and Basins between these exterior mountain ranges.

These major divisions can be readily identified in their general outline on the accompanying map of physical features. Roughly, the proportion of the combined area of the interior and coastal plains to the remainder of the country is about 4 to 3. Differences in structure, process of formation, and stage of development, give rise within these major divisions to distinct characteristics in relief forms and to contrasts in elevation which are important regionally and locally in affecting land use. Subdivisions that recognize such distinctions are essential to an adequate treatment but cannot be noted here for lack of space.

Drainage is controlled by the land relief. Running water receives its impulse and direction from the slope and position of the mountain ranges and smaller elevations. In the United States there are four major drainage divisions directed toward the east, the west, the south, and the north. The Continental Divide, separating the waters that flow to the Pacific from those that flow to the Atlantic and Arctic oceans, runs mainly along the crest of the Rocky Mountain system. The western slope draining into the Pacific comprises some 609,000 square miles or 20.5 percent of the area of the United States; the area draining south into the Gulf of Mexico comprises 1,662,000 square miles, or 55.9 percent; the area draining east embraces 408,500 square miles, or 13.7 percent; and the area draining to the north into Hudson Bay comprises about 57,700 square miles or 1.9 percent. The remainder is composed of a number of basins without drainage outlet. Two of these basins, the Plains of San Augustin in New Mexico and the Great Divide Basin in Wyoming, are part of the Continental Divide. Large portions of the Trans-Pecos Country, the Estancia and Tularosa Valleys in New Mexico, and the Salt Basin in Texas, are also without drainage outlet. The most extensive area of this kind lies west of the Continental Divide, comprising the Great Basin between the Rocky Mountains and the Sierra Nevada, and its southward extension, the Mojave Desert. All these basins aggregate about 236,500 square miles, or 8 percent of the land area of the United States.

INFLUENCES OF LAND RELIEF ON CLIMATE

Climate, considered as the sequence of meteorological events at a given place, is the most unstable of the factors comprising the natural environment but as a factor in shaping biological conditions it is the most powerful. Temperature decreases with altitude at an average rate of about 3° F. for every 1,000 feet, but there is no constant relationship between them. The ratio changes with locality and season. In fact, in mountainous country and especially during the winter months, temperature inversions are not uncommon. But, as a general principle, it is true that with increasing altitude we advance vertically toward the Frigid Zone.

Mountainous country shows a much greater diversity in temperature conditions within relative short distances than plains. In wind-protected valleys the air is held much longer in contact with the land and is heated more. The maximum temperature for the United States, recorded in Death Valley, Calif., is of this nature. In higher altitudes, 5,000 to 6,000 feet or more, insolation is more intense than on lower levels. Solid impurities, such as smoke and dust, suspended in the atmosphere and its content of water vapor diminish with altitude, consequently insolation normally increases with altitude. Although the air may be cool, soil and rocks exposed to the sun become remarkably hot. Similarly, radiation in this clear and rarefied atmosphere is more rapid. After sundown, the air cools rapidly, becomes denser and heavier with a tendency to drain into the valleys, displacing the warmer air. Unseasonal frost resulting from air drainage is in some localities a hazard to land use.

Slope exposure is a relief feature that modifies local temperature conditions. In northern latitudes slopes with southern exposures receive a greater amount of insolation than slopes facing toward the north. As a result, ground temperatures and evaporation are considerably higher on slopes with southern than on those with northern exposure. In regions in which precipitation is near the minimum for tree growth, as in some of the western mountain ranges and shallow valleys in the plains, the slopes facing south are grass land while those facing north support timber. For the same reason the timber line on southern and western mountain slopes is higher than on the northern.

Cool climate, on account of altitude, affects agriculture in the United States in a number of places. At higher altitudes in the Central Appalachian Plateau corn is an uncertain crop, and in much of the Rocky Mountain and Interior Plateau regions it is grown scarcely at all, except in the lower valleys. Wheat reaches its cool limits only at high elevations in the Rocky Mountains. The northern boundary of the Cotton Belt is about 2 degrees of latitude farther north in the lowlands of the Mississippi bottoms and the lowlands along the Atlantic Coastal Plain than it is in the higher Piedmont and the southern slope of the Ozarks.

The moisture-holding capacity of the atmosphere is greatly reduced with decrease in temperature. At a temperature of 80° F. the saturation point is reached when the atmosphere contains 10.93 grains of water vapor per cubic foot; at 40° F. it falls to 2.85 grains; at zero temperature to 0.48; and at 40 below zero is reduced to 0.05 grains. It is evident that by far the greatest amount of water vapor in the atmosphere is contained in the warmer lower strata. Moisture-freighted air currents, deflected upward by mountains into higher levels, are cooled and they discharge a considerable portion of the water in the ascent. The heaviest precipitation in the United States occurs on mountain slopes facing the ocean. On the Atlantic slope the warm on-shore winds from the South Atlantic and the Gulf of Mexico have to rise in passing the Southern Appalachians, and as a consequence the heaviest precipitation in the eastern United States is found there.

On the Pacific coast conditions are different during the cool than during the warm season. These conditions affect the California coast more than the north Pacific coast. Before the winds from the west reach the land they pass over a cold ocean current from the north, which cools the lower air strata during the summer months. An inversion of normal conditions is the result. The ocean breezes saturated with moisture, frequently in the form of fog, rise into warmer strata in their passage over the Coastal Range, the water-holding capacity is increased, fogs dissolve, and precipitation is usually lacking or low on the California Coastal Range during the summer months. Precipitation is even lower in the hot interior valleys.

A much greater amount of moisture is liberated in the second ascent over the Sierra Nevada. Here temperature decreases with altitude and precipitation increases on the western slopes up to about 6,000 feet. The eastern slopes are in the rain shadow of the mountains and arid conditions prevail in the valleys and lower plateaus to the east.

Along the north Pacific coast conditions are not so abnormal. The Coast Range receives here an ample share of the moisture brought in from the ocean by the winds.

The whole pattern of precipitation distribution on the Pacific Coast States follows closely the arrangement of the mountain systems. Great contrasts in relief produce great contrasts in amounts of precipitation within short distances—the greatest in the United States. On the western upper slopes of the Olympic Mountains, the average annual precipitation probably approaches or even exceeds 200 inches. At the foot of the eastern slope, it falls locally below 20 inches. The distance between these two extremes is about 40 miles. On the western slope of the Sierra Nevada in central California the average annual precipitation is locally 70 to 80 inches; in Death Valley, some 60 miles to the east, it falls to about 1 inch.

The effects of the barrier formed by the Sierra Nevada and the Cascade Mountains to the eastward movement of the humid air from the Pacific extend over the entire western half of the United States. In the Intermountain Plateau region only the higher portions of the mountain ranges receive sufficient precipitation to support a forest growth, the lower portions being semi-arid or arid. This is true also of the Rocky Mountain region, and the moisture deficiency extends over a broad belt of the Great Plains to the east. About one-third of the United States receives inadequate precipitation for arable farming or forest, and can produce little more than a scanty growth of pasture plants. Most of this area is deprived of a more copious water supply as a result of the peculiar arrangement of the mountain barriers, which intercept much of the moisture before it can be transported farther inland.

INFLUENCE OF LAND RELIEF ON SOILS

Soils are the third important factor in the natural environment. A marked change in the character of the soil means a modification in the natural environment, and is usually reflected in the plant life it supports. Soil characteristics, acquired during the period of development, are recorded in structure, texture, color, and chemical composition, and serve as distinguishing marks in soil classification. Some of the soil characteristics are derived from the parent material, others from climate, from vegetation cover, and from relief.

Relief as a factor in soil development acts primarily through the instrumentality of slope gradient, the resulting drainage conditions determining in large measure the degree of stability of the surface soil material. A considerable time of undisturbed development is necessary to produce mature soils in agreement with the natural environment complex. Whenever and wherever, therefore, the soil-forming processes are out of pace with the processes of depletion or accretion of surface material, normal soil development cannot take place. Land areas with undeveloped drainage systems, level or nearly level land with inadequate drainage, undulating to rolling country well drained, and steeply sloping hill and mountain sites with rapid run-off, will usually exhibit distinct soil characteristics. As a consequence, the distribution

Figure 2.—Altitude in the western third of the United States, and in the mountainous portions of the East also, is as important a factor as latitude in influencing the climatic conditions and the natural vegetation. In general temperature diminishes about 1° F. for each 300 feet increase in altitude. This may be compared with a decrease of about 1° for each 50 miles increase in latitude in the Mississippi Valley in summer and for each 20 to 30 miles in winter. In the interior of the continent, remote from marine influence, an increase of 1,000 feet in altitude is generally equivalent in its effect on average annual temperature to about 2° of latitude, or 135 to 140 miles.

The mountainous relief generally associated with altitude exerts a profound influence upon moisture conditions likewise. Most of the mountain ranges in the East, as well as in the West, trend more or less north and south, while the prevailing air drift is from the west. The winds, forced to rise on approaching these mountain ranges, become cooler and release a portion of their moisture in the form of rain or snow. The western slopes of the mountain ranges tend, therefore, to be moist; while the eastern slopes, where the air is descending and becoming warmer, tend to be dry. This contrast is much more marked in the mountains of the Western States than in the Appalachian Ranges of the East, which are lower, trend northeast and southwest instead of north and south, and are influenced occasionally by moisture-bearing winds from the Atlantic Ocean to the east. The dry or "rain-shadow" belts along the eastern margin of the mountain ranges in the West may extend leeward 100 miles or more. As a consequence of these climatic conditions many of the mountains in the West are clothed with forest, whereas the valleys and intervening plateaus are characteristically grassland or support a desert-shrub vegetation.

Altitude and the lay of the land exert also a strong influence upon soil conditions. All soils on sloping land are in motion. The movement may be slow where the soil is covered with forest or grass, or fast where the intertillage of crops, such as cotton and corn, has exposed the soil to erosion. Because of the many influences of topographic conditions upon climate, natural vegetation, and soil, this map of "physical features", or, to be more precise, of altitude, is placed first in this series of maps descriptive of the physical basis of American agriculture.

of certain soil types is almost coextensive with the relief features commonly associated with these soils.

Undulating and gently rolling land which, although well drained, permits maximum absorption of precipitation water, and is not susceptible to damaging erosion, possesses the kind of relief that promotes soil development to maturity. On steeply sloping land run-off water moves rapidly with increased erosive power. The rate of erosion depends, however, on many other factors besides gradient of slope. Soil texture and structure; amount, intensity, and seasonal distribution of precipitation; length of frost-free season; and type of land use, are all factors which accelerate or retard erosion. Under natural conditions, with a soil-binding vegetation cover in the form of forest, brush, or grass, erosion activity is generally slow even on relatively steep slopes.

The conditions change with the clearing of the forest and the breaking of the sod for cultivated crops. Even on gentle slopes with gradients from 4 to 8 percent the removal of surface soil may be serious. Soil losses from erosion on cultivated land depend also on maintenance of organic matter in soil, method of cultivation, kind of crops grown, and system of crop rotation. Sheet erosion and gullying are the two forms of water erosion. Whenever the rate of surface-soil removal exceeds that of the soil-forming processes, retrograde development of the soil results. Gullying goes even farther in that it is likely to change rapidly the surface form of the land, and may ruin the land for crop production.

Wind erosion is most severe in the arid and semiarid regions. Strong winds and storms, sweeping up the dust and sand particles, are here as much a transport agent as running water. The load-carrying capacity of the air is dependent on the force of the wind and the size of the soil particles. Finer particles can be lifted higher, suspended longer, and transported farther than the coarser. Redeposition occurs on that account in textural assortment, with mountain ranges and bluffs acting as an obstacle to equal distribution. Sands and sand dunes found in this region are usually located at the foot of the western slopes of ranges, where the prevailing west winds deposit the sand loads, being unable to lift them over the obstruction. Finer particles are carried higher and transported farther east. On the large soil map in this Atlas, instances of such sorting action can readily be identified in the lower California valleys, the Columbia Basin, the San Luis Valley, and in the upper Rio Grande and Pecos Valleys. Much of the dust swept up by the wind in arid districts is carried into more humid areas and precipitated, thus accumulating as loess. Many parts of the Interior Plains and the higher portions of the Columbia and Snake River Basins are covered with a loess blanket.

DIRECT INFLUENCE OF RELIEF ON LAND USE

The modification of the factors composing the natural environment through the influence of surface relief affects land use profoundly. A more direct reaction to surface relief is registered when the use of the land requires the sustained application of productive energy to maintain annual crop yields. In this case, surface relief not only facilitates or impedes operations on individual farms, but also determines, within climatic limits, the distribution of crop-production areas. In fact, the settlement and development of the Nation have been and still are influenced profoundly by the physiographic structure of the continent.

Colonization by Europeans along the Atlantic coast began early in the seventeenth century. Nevertheless, up to the third quarter of the eighteenth century settlement was confined to the country between the Appalachians and the coast. For over a hundred years, the Appalachian Mountains formed the frontier and checked the westward movement of the settlers. But after the passes in the barrier were found, and roads and railroads were built, the stream of settlers moving west gathered such momentum that within the next hundred years the vast interior plains were settled and agriculturally developed—an area about four times as large as that occupied in the previous two centuries. The plains offered many natural advantages. There were immense stretches of nearly level land with fertile soil, most of it ready for the plow without clearing. The lure of the plains became so strong that it not only encouraged many of the eastern hill-land farmers to leave their homes and move to the West, but also induced immigration from Europe.

Other important events profoundly affecting agriculture occurred during the last century. Technical improvements kept pace with territorial expansion. Communication and transportation systems were extended and improved, labor-saving implements and machinery were invented and put into use, and animate energy was partially displaced by inanimate energy, even on farms. Agriculture received a good share of the benefits derived from all these innovations. But all parts of the country did not and could not share to the same extent in the benefits of these technical achievements. The routes of roads, canals, and railroads usually follow lines of least obstruction. There are few obstacles in the plains for roads and railroads to circumvent or overcome. A dense, largely straight-line, network of communication lines is the result. No such pattern could be developed in the hilly and mountainous sections of the country. Modern engineering is prepared to surmount almost any natural obstacle, but the cost of construction and maintenance of highways and railroads in rugged areas is considerably greater than on level land. Traffic is slowed up and its energy requirements are increased. As a consequence, many parts of our rather densely settled, hilly districts in the East are as yet comparatively inaccessible.

Agriculture is obstructed in the hilly regions in much the same way. The advance in productivity of labor with the use of machinery is no less remarkable in agriculture than in industry. For example,[1] perhaps an extreme example: About 1830 the man-labor time required to grow and harvest with hand methods (one bottom plow, hand sowing, reaping with sickle, and threshing with flail) 1 acre of winter wheat yielding 20 bushels was about 58 hours. In 1930 the approximate man-labor requirements with machine methods in the Great Plains area for the production of the same quantity of wheat per acre was about 3 hours.

Machine farming is favored by large unbroken fields, but for many of the general types of farming in which a number of different crops are grown in rotation, such large outfits cannot be used as are found advantageous in wheat farming. Improved implements and machinery for many of these operations have been in use for decades, but the area of their potential use is restricted to land sufficiently smooth to make their use feasible. The plains, therefore, invite the use of the machine, while the rougher districts have to reject them. It is an open question to what extent the plains furnished the incentive to mechanized crop production. Certain it is that a great portion of the semiarid plains could not have been used for crops without machinery. The contest between mechanical efficiency and the hazard of sporadically deficient rainfall and consequent crop failure, is not yet settled in much of this region.

American agriculture for a number of decades has been under the spell of ever-increasing mechanization. As a result, the center of agricultural production moved almost continuously westward, prior to 1930. Expansion of cultivation in the West was accompanied by more or less abandonment in the East.

The influence of level or gently rolling land upon the use of farm machinery, and this, in turn, upon the acreage cultivated per male worker on farms, is illustrated in the maps (figs. 3 and 4). The Great Plains region stands out prominently in contrast to the rougher sections in the East. In some counties in the Southern Appalachians, where most of the land is too steep for the use of wheeled implements and much of the field work has to be done with hand tools, the value of implements and machinery is often less than $50 per male worker on the farm and the average extent of cultivated land per male worker is about 7 acres. Farms are small, and the value of farm products per farm is low. The subsistence type of farming is prevalent in this region. At the other extreme, on the western plains, some wheat-growing counties are found in which the cultivated land, exclusive of land that lies idle and fallow, is over 300 acres with an investment of over $2,000 per male worker on farms. Commercial farming with large-scale operation and a relatively high value of products per farm is here characteristic.

In many parts of the country the interrelationship existing between character of land relief, value of mechanical equipment, and the amount of land a farmer can cultivate is not so well defined as in the two cited cases. Other factors, that cannot be eliminated, tend to obscure the true relationship. First of all, the value of implements and machinery, as reported by the census, includes all kinds of tools or machinery found on the farm, even automobiles, without distinction as to whether they are used in the cultivation of the land. For this reason, dairy and some crop-specialty areas in the North Central and Northeastern States show a relatively higher investment in implements than the cultivation of the land would require.

The cotton farmers in the South furnish another exception. Although much of the land on which cotton is grown is smooth enough for machine cultivation, cotton is a crop that, in the humid region and in fact nearly everywhere, still requires picking by hand, which limits the number of acres a farmer can harvest.

In the Intermountain Plateau and Basin region and in the sand hills of Nebraska, with hay as the main crop, a moderate investment in machinery permits the harvesting of a large acreage. It should be noted that, for the arid country, these maps are likely to create an erroneous impression in that they give a distorted picture in regard to the area affected. Owing to the use of counties as units, the high value of equipment and large acreage of cultivated land per male worker on farms apply only to a very small portion of the total area and a small number of farms.

Surface relief, through its influence in the formation of a more or less favorable natural environment for human occupancy, necessarily has influenced land settlement. Population distribution on the basis of elevation above sea level alone shows marked differences. Of the Nation's population about 95 percent inhabits land that has an elevation of less than 2,000 feet, whereas the area of such land comprises only about 57 percent of the total land area of the United States. Climatic conditions arising from the relief features account in part for this distribution.

As a factor in influencing land utilization and agricultural development, land relief is as basic as climate or character of soil. Moreover, land relief determines in large measure the climate and the soil. For this reason the relief map has been placed first in the series of physical maps, and in order that the reader may trace some of the relationships, most of the major maps are printed on a base of hachured relief.

F. J. Marschner.

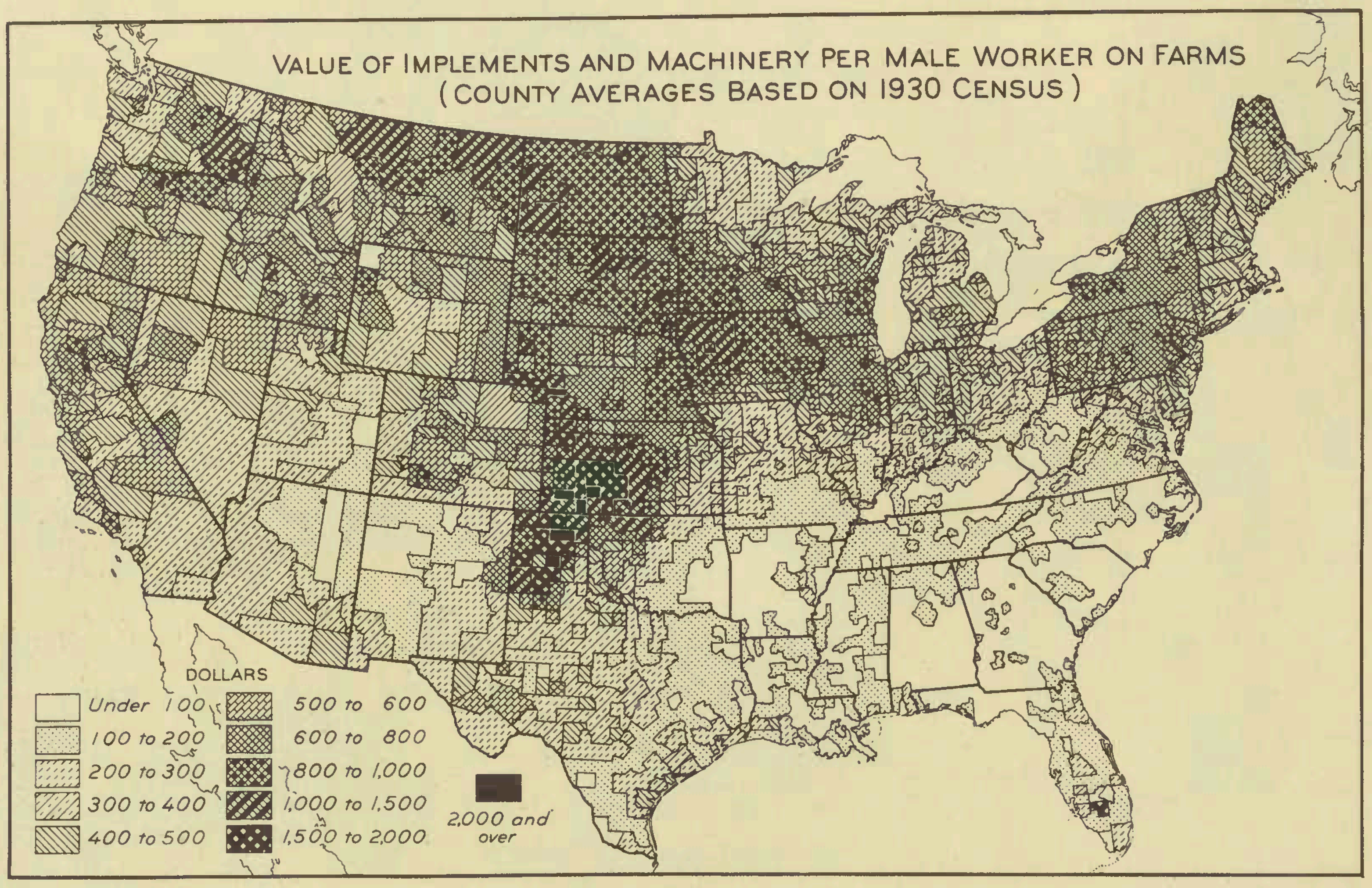


Figure 2.—The use of agricultural machinery is favored by level or gently rolling land, and is hindered in hilly regions. Substitution of animal and especially mechanical power for human muscle has occurred, therefore, most fully in the Great Plains region and on the level or rolling lands of the Corn Belt and the Lake Plains. Portions of the Cotton Belt are also almost level, but the absence of a successful cotton picker has retarded the use of machinery.

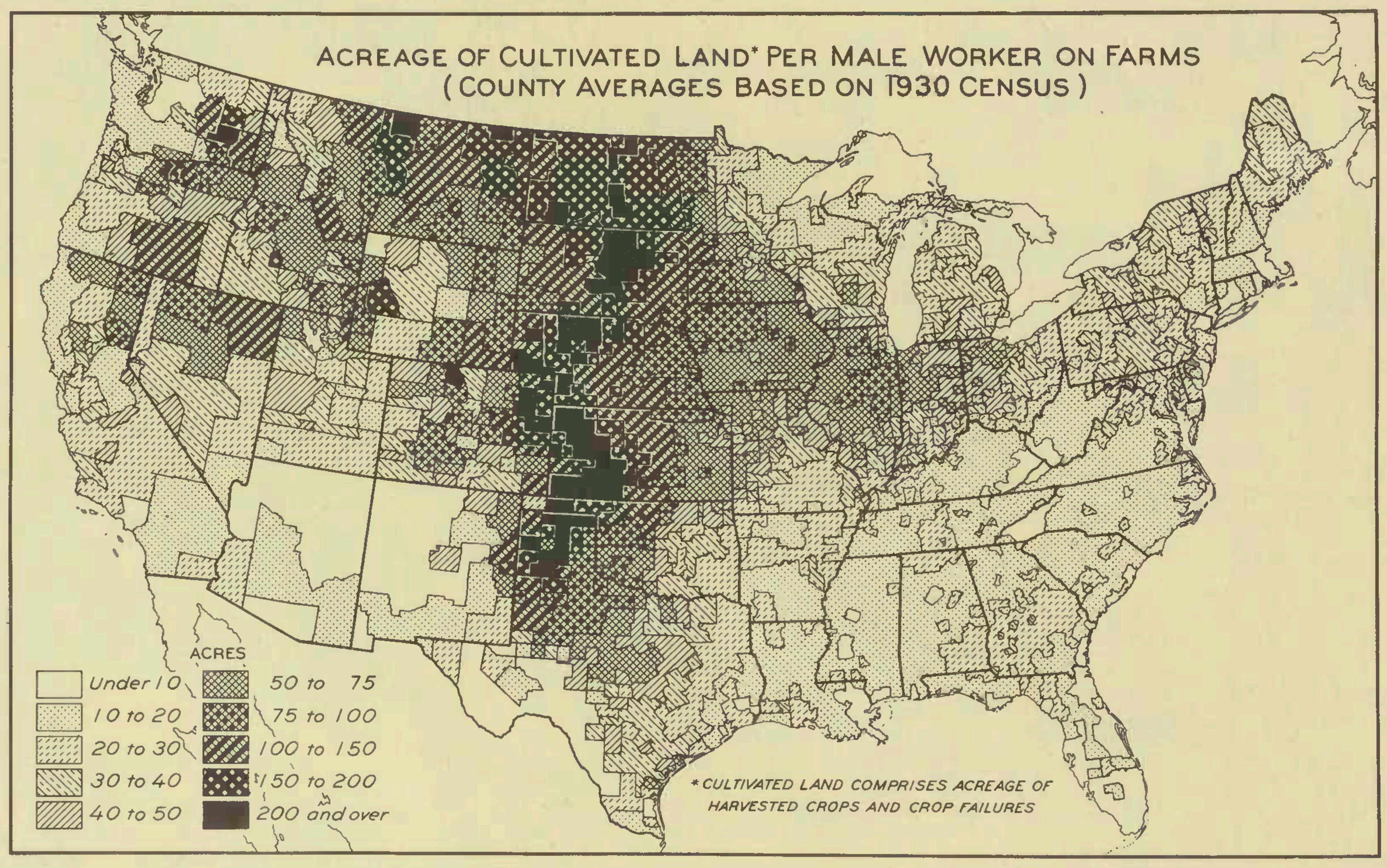


Figure 3.—Production per worker on farms is closely related to the use of machinery, and is reflected in the acreage of cultivated land per male worker. In the Great Plains the area of cultivated land per male worker exceeds 200 acres in many counties. By contrast, there are a number of counties in the Southern Appalachians, in which the land is too rugged for the use of machinery and agricultural practices of the 18th century still prevail. Here the average cultivated acreage per worker is less than 10 acres.

[1] Hurst, W. M. and Church, L. M.—Power and Machinery in Agriculture. United States Department of Agriculture Miscellaneous Publication No. 157, pp. 2 and 3. 1933.

Issued, November, 1928

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

ATLAS
OF
AMERICAN AGRICULTURE

Prepared under the Supervision of O. E. BAKER, Senior Agricultural Economist
Bureau of Agricultural Economics, NILS A. OLSEN, Chief

CLIMATE

Contribution from the U. S. Weather Bureau, CHARLES F. MARVIN, Chief

TEMPERATURE, SUNSHINE, AND WIND

BY

JOSEPH B. KINCER
Principal Meteorologist, U. S. Weather Bureau

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON
1928

Figure A.—This map shows the location and relative density in different sections of the country of the Weather Bureau stations. The location of the 200 stations of the first order (daily telegraphic stations) is shown by a hollow circle. The location of the cooperative stations is shown by a red dot. Temperature observations are not made at all of the stations shown, but 2,300 well-distributed temperature records were used in compiling data for this section of the Atlas. The number of stations used for each of the several charts is indicated thereon. The more important mountain ranges and river valleys are also shown on this map by means of hachuring. These physiographic features exercise an important influence in determining temperature conditions

SELECTED REFERENCES

TEMPERATURE

Abbot, C. G., and Fowle, F. E.: Volcanoes and Climate, Smithsonian Misc. Coll., vol. 60, pp. 24. Washington, 1913.

Baker, O. E., and Stine, O. C.: Climate of the Cotton Belt. Mo. Weather Rev., vol. 47, pp. 487–9. 1919.

Batchelor, L. D., and West, F. L.: Variation in Minimum Temperatures Due to the Topography of a Mountain Valley in Relation to Fruit Growing. Utah Agr. Exp. Sta. Bull. 141. 1915.

Bigelow, Frank Hagar: The Daily Normal Temperature and the Daily Normal Precipitation of the United States. U. S. Weather Bur. Bull. R, 186 pp., tables. 1908.

——— Report on the Temperatures and Vapor Tensions of the United States Reduced to a Homogenous System of 24 Hourly Observations for the 33-Year Interval, 1873–1905. U. S. Weather Bur., Bull. S, 302 pp., incl. tables and charts. Washington, 1909.

Blair, W. R.: Slope and Valley Air Temperatures. Mo. Weather Rev., vol. 44, p. 677. 1916.

Blair, T. A.: Some Temperature Correlations in the United States. Mo. Weather Rev., vol. 45, p. 444. 1917.

Bliss, George S.: Forecasting Minimum Temperatures for the Cranberry Bogs of New Jersey. Mo. Weather Rev., vol. 50, pp. 529–33. 1922.

Bouyoucos, George: Soil Temperature. Mich. Agr. Exp. Sta. Bull. no. 26. 1916.

——— Degree of Temperature to Which Soils May be Cooled Without Freezing. Jour. of Agr. Res., vol. 20, no. 4, pp. 267–9. 1920.

Bradford, F. C.: The Relation of Temperature to Blossoming in the Apple and the Peach. Mo. Agr. Exp. Sta. Res. Bull. no. 53. 1922.

Brooks, Charles F.: The "Old-Fashioned" Winter of 1917–18. Geographic Review, vol. 5, no. 5. 1918.

Burnham, G. H.: The Weather Element in Railroading. Mo. Weather Rev., vol. 50, pp. 1–7. 1922.

Coville, F. V.: The Influence of Cold in Stimulating the Growth of Plants. Jour. of Agr. Res., vol. 20, no. 2, pp. 151–60. 1920.

Cox, H. J.: Thermal Belts and Fruit-Growing in North Carolina. Mo. Weather Rev. Suppl. 19, charts, illustrations. 1922.

——— Differences Between the Readings of Sheltered and Unsheltered Thermometers in Field Work. Mo. Weather Rev., vol. 48, pp. 711–12. 1920.

Day, Preston C.: The Cold Spring of 1917. Mo. Weather Rev., vol. 45, pp. 285–9. 1917.

——— The Cold Winter of 1917–18. Mo. Weather Rev., vol. 46, pp. 57–80. 1918.

Fawcett, H. S.: Relation of Temperature to Growth and Infection in the Citrus Scab Fungus (Cladosporium Citri). Jour. of Agr. Res., vol. 21, no. 4, p. 243. 1921.

Fowle, F. E.: (*See* Abbot and Fowle.)

Gladwin, F. E.: Winter Injury to Grapes. N. Y. Agr. Exp. Sta. Bull. 433. 1917.

Gordon, James H.: Temperature Survey of the Salt River Valley, Arizona. Mo. Weather Rev., vol. 49, pp. 271–4. 1921.

Haines, E. H.: Influence of Varying Soil Conditions on Night Air Temperatures. Mo. Weather Rev., vol. 50, pp. 363–6. 1922.

Hallenbeck, Cleve.: Night Temperature Studies in the Roswell Fruit District. Mo. Weather Rev., vol. 46, pp. 364–73. 1918.

Henry, A. J.: Climatology of the United States. U. S. Weather Bur., Bulletin Q, 1012 p. 1906.

——— Sunspots and Terrestrial Temperature in the United States. Mo. Weather Rev., vol. 51, pp. 243–9. 1923.

Hopkins, A. D.: Periodical Events and Natural Law as Guides to Agricultural Research and Practice. Mo. Weather Rev. Suppl. 9. 1918.

——— Bioclimatic Zones Determined by Meteorological Data. Mo. Weather Rev., vol. 49, pp. 299–300. 1921.

Humphreys, W. J.: Physics of the Air. The Franklin Inst., Phila. 1920.

——— Factors of Climatic Control. Jour. Franklin Inst., Phila., Dec. 1919–Jan. 1920. (*See also* Mo. Weather Rev., vol. 48, pp. 535–7, 1920, for review by Ellsworth Huntington.)

Hutt, W. N.: Thermal Belts from the Horticultural Viewpoint. Mo. Weather Rev. Suppl. 19. 1922.

Keen, B. A., and Russel, E. J.: Factors Determining Soil Temperature. Jour. of Agr. Sci., vol. 11, part 3, 1921. Rothamsted, England.

Kincer, Joseph B.: Relation Between Vegetative and Frostless Periods. Mo. Weather Rev., vol. 47, pp. 106–10. 1919.

——— Temperature Influence on Planting and Harvest Dates. Mo. Weather Rev., vol. 47, pp. 312–23. 1919.

Livingston, Burton E., and Shreve, Forrest: The Distribution of Vegetation in the United States as Related to Climatic Conditions. Carnegie Inst., Washington, 1921.

Marvin, Charles F.: Solar Radiation Intensities and Terrestrial Weather. Mo. Weather Rev., vol. 51, pp. 186–8. 1923.

McAdie, Alexander: Mean Temperatures and Their Corrections in the United States. At head of title: United States of America, War Department. x, 45 pp., tables. 1891.

McGinty, R. A.: Horticulture at High Altitudes. Colo. Agr. Exp. Sta. Bull. no. 256. 1920.

Miller, Edwin C., and Saunders, A. R.: Some Observations on the Temperature of the Leaves of Crop Plants. Jour. of Agr. Res., vol. 26, no. 1. 1923.

Palmer, A. H.: Death Valley, California, the Hottest Known Region. Mo. Weather Rev., vol. 50, pp. 10–13. 1922.

Reeder, George: Ground Temperatures Compared with Air Temperatures in a Shelter. Mo. Weather Rev., vol. 48, pp. 637–9. 1920.

Russel, E. J. (*See* Keen and Russel.)

Salmon, S. C.: The Relation of Winter Temperature to the Distribution of Winter and Spring Grains in the United States. Jour. of Amer. Soc. of Agron., vol. 9, no. 1. 1917.

Saunders, A. R. (*See* Miller and Saunders.)

Schott, Charles A.: Tables, Distribution, and Variations of the Atmospheric Temperature in the United States and Some Adjacent Parts of America. xvi, 345 pp. tables. charts., Smithsonian contributions to knowledge, 277. Washington, 1876.

Seeley, D. A.: Relation between Temperature and Crops. Mo. Weather Rev., vol. 45, pp. 354–9. 1917.

Shreve, Forrest. (*See* Livingston and Shreve.)

Sinclair, John G.: Temperatures of the Soil and Air in a Desert. Mo. Weather Rev., vol. 50, pp. 142–4. 1922.

Smith, J. Warren: Phenological Dates and Meteorological Data recorded by Thomas Mikesell at Wauseon, Ohio. Mo. Weather Rev. Suppl. 2. 1915.

Smith J. Warren, and others: Predicting Minimum Temperatures from Hygrometric Data. Mo. Weather Rev. Suppl. 16. 1920.

Stockman, William B.: Temperature and Relative Humidity Data. U. S. Weather Bur., Bull. O, 29 pp., 2 charts. 1905.

Summers, John N.: Effect of Low Temperature on the Hatching of Gypsy Moth Eggs. U. S. Dept. of Agr. Bull. 1080. 1922.

Taylor, George F. (*See* Wright and Taylor.)

Thiessen, Alfred H.: Story of the Thermometer and Its Uses in Agriculture. Yearbook, Dept. of Agri., pp. 157–66. 1914.

Tottingham, W. R.: Temperature Effects in Plant Metabolism. Jour. of Agr. Res., vol. 25, no. 1. 1923.

U. S. Patent Office: Results of Meteorological Observations Made under the Direction of the United States Patent Office and the Smithsonian Institution from the year 1854 to 1859, inclusive, being a Report of the Commissioner of Patents Made at the First Session of the Thirty-sixth Congress. 2 vol. (36th Cong., 1st sess., House Ex. doc. 55.) 1861–64.

U. S. Signal Office: Charts Showing Maximum and Minimum Temperatures by Decades, for All Years. Cover, title, 37 charts. Washington, 1891.

——— Normal Temperature Charts by Decades for the United States and the Dominion of Canada. Cover, title, 72 charts. At head of title: United States of America, War Department. Washington, 1891.

U. S. Surgeon General's Office: Meteorological Register for the Years 1822, 1823, 1824, and 1825, from Observations Made by the Surgeons of the Army, at the Military Posts of the United States. 63 pp. fold. map. Washington, 1826.

——— Meteorological Register for the years 1826, 1827, 1828, 1829, and 1830. 161 pp. fold. map. Philadelphia, New Orleans, 1840.

——— Meteorological Register for Twelve Years, from 1831 to 1842, Inclusive. 324 pp. Washington, 1851.

——— Army Meteorological Register, for Twelve Years, from 1843 to 1854, Inclusive. xi, 763, 3 pp., 10 charts. Washington, 1855.

——— Statistical Report on the Sickness and Mortality in the Army of the United States, Compiled from Records of the Surgeon General's Office; Embracing a Period of Sixteen Years, from January, 1839, to January, 1855, by Richard H. Coolidge. 703 pp. tables. fold. map. (34th Cong., 1st sess., Senate Ex. doc. no. 96.) 1856.

U. S. Weather Bureau: Report of the Chief of the Weather Bureau, 1896–97. 431 pp. plates. illus. tables. (Normal Variability of Temperature.) Table 5. pp. 284–5. 1897.

——— Summaries of Climatological Data by Sections. Prepared by the Climatological Division. 2 vol. maps. charts. tables. (U. S. Weather Bur., Bull. W.) 1912.

——— Temperature Departures, Monthly and Annual, in the United States, January, 1873, to June, 1909, Inclusive. Bull. U, 584 charts. 1911.

——— Temperature Gradients in Latitude, Longitude, and Altitude. Report of the Chief of the Weather Bureau, 1900–1901, vol. 2, chap. 4, pp. 361–419. charts. tables. 1902.

——— Temperature statistics in extenso for the various parts of the United States are available in the following:

——— State Weather Services. Reports. (*See* Fassig. Statistics of State Weather Services.) W. B. no 81. Washington, 1896.

——— Monthly Reports of the Climate and Crop Service. (Climatological Service.) 1896 to June, 1909, and 1914 to date.

——— Monthly Weather Review, July, 1909–1913.

——— Climatological Data for the United States by Sections. (Monthly with annual summary.)

Ward, Robert DeC.: Some Characteristics of United States Temperature. Mo. Weather Rev., vol. 49, pp. 595–608, 20 charts following p. 610. 1921.

——— Bibliographic Notes on the Temperature Charts of the United States. Mo. Weather Rev., vol. 49, pp. 277–280. 1921.

——— Hot Waves, Hot Winds, and Chinook Winds in the United States. Sci. Monthly, vol. 17, no. 2, pp. 146–67. 1923.

——— Cold Waves, Northers, and Blizzards in the United States. Sci. Monthly, vol. 16, no. 5, pp. 440–70. 1923.

West, F. L. (*See* Batchelor and West.)

Woolard, E. W.: Historical Note on Charts of the Distribution of Temperature, Pressure, and Winds over the Surface of the Earth. Mo. Weather Rev., vol. 48, pp. 408–11. 1920.

Wright, R. C., and Taylor, George F.: The Freezing Temperatures of Some Fruits, Vegetables, and Cut Flowers. U. S. Dept. of Agr. Bul. 1133. 1923.

Young, Floyd D.: Effect of Topography on Temperature Distribution in Southern California. The Calif. Citrograph, vol. 5, no. 7. 1920.

——— Influence of Exposure on Temperature Observations. Mo. Weather Rev., vol. 48, pp. 709–11. 1920.

——— Nocturnal Temperature Inversions in Oregon and California. Mo. Weather Rev., vol. 49, pp. 138–48. 14 figs. tables. 1921.

——— Notes on the January, 1922, Freeze in Southern California. Mo. Weather Rev., vol. 51, pp. 581–85. 1923.

——— Substituting Fruit Temperatures for Air Temperatures in Regulating Orchard Heating for Oranges. Mo. Weather Rev., vol. 52, pp. 381–87. 1924.

SUNSHINE

Allard, H. A. (*See* Garner and Allard.)

Garner, W. W., and Allard, H. A.: Effect of the Relative Length of Day and Night and Other Factors of the Environment on Growth and Reproduction in Plants. Jour. of Agr. Res. March, 1920.

Hand, Irving F. (*See* Kimball and Hand.)

Hearn, George D.: Relation of Sunlight to Plant Development. Mo. Weather Rev., vol. 50, p. 423. 1922.

Kimball, H. H.: **Duration and Intensity of Twilight.** Mo. Weather Rev., vol. 44, pp. 614–26. 1916.

Kimball, H. H., and Hand, Irving F.: Daylight Illumination on Horizontal, Vertical, and Sloping Surfaces. Mo. Weather Rev., vol. 20, pp. 615–28. 1922.

Kincer, Joseph B.: Sunshine in the United States. Mo. Weather Rev., vol. 48, pp. 12–17. 1920.

Palmer, Andrew H.: The Agricultural Significance of Sunshine as Illustrated in California. Mo. Weather Rev., vol. 48, pp. 151–54. 1920.

Seeley, Dewey A.: The Heating of Plants in Sunlight as a Factor in Growth. Mo. Weather Rev. vol. 47, pp. 327–28. 1919.

Stewart, J. B.: Effect of Shading on Soil Conditions. U. S. Bur. of Soils Bul. no. 39. 1907.

Ward, Robert DeC.: Bibliographic Note on Sunshine in the United States. Mo. Weather Rev., vol. 47, pp. 794–5. 1919.

WIND

Beck, Anne Louise: The Earth's Atmosphere as a Circular Vortex. Mo. Weather Rev., vol. 50, pp. 393–401. 1922.

Bowie, Edward H., and Weightman, R. Hanson: Types of Storms in the United States and Their Average Movement. Mo. Weather Rev. Suppl. 1. 1914.

——— Types of Anticyclones in the United States and Their Average Movement. Mo. Weather Rev. Suppl. 4. 1917.

Day, Preston C.: The Winds of the United States and Their Economic Uses. U. S. Dept. Agr. Yearbook, 1911, pp. 337–50.

Fuller, P. E.: The Use of Windmills in Irrigation in the Semi-arid West. Farmers' Bul. 866, U. S. Dept. Agr. 1917.

Gregg, Willis R.: An Aerological Survey of the United States. (Results of Observations by Means of Kites.) Mo. Weather Rev., vol. 50, pp. 229–42. 1920.

Gregg, Willis R., and Van Zant, J. Parker: The Wind Factor in Flight. (Analysis of One Year's Record of the Air Mail.) Mo. Weather Rev., vol. 51, pp. 111–25. 1920.

Marvin, Charles F.: Air Drainage Explained. (With Reference to Temperature Influence.) Mo. Weather Rev., vol. 42, pp. 583–85. 1914.

——— The Law of the Geoidal Slope and Fallacies in Dynamic Meteorology. Mo. Weather Rev., vol. 48, pp. 565–82. 1920.

Mitchell, Charles L.: West Indian Hurricanes and Other Tropical Cyclones of the North Atlantic Ocean. Mo. Weather Rev. Suppl. 24. 1924.

Samuels, L. T.: Correlations Between Wind Velocities at the Surface and Those in the Free Air. Mo. Weather Rev., vol. 50, pp. 83–89. 1922.

Van Zant, J. Parker. (*See* Gregg and Van Zant.)

Wieghtman, R. Hanson. (*See* Bowie and Weightman.)

TEMPERATURE

Temperature is one of the most important factors that make up the climate of a region. Plant and animal life is constantly under the influence of the temperature of the air near the earth's surface, and it is with this temperature that we are mostly concerned as regards agricultural enterprises and our bodily comfort. For climatological purposes the measure of temperature is obtained from thermometers freely exposed to the air near the surface of the earth and shielded from the direct rays of the sun, but in such a manner as not materially to obstruct the atmospheric circulation.

Source of data.—The records made by cooperative observers of the Weather Bureau have been largely used in preparing the charts and graphs here presented. These stations are in most cases located in the open country and small towns, where the instruments are more or less free from the artificial influences that frequently affect the temperature records made at the first order Weather Bureau stations in the larger cities. The records are made by standard maximum and minimum thermometers, exposed in approved shelters, usually at an elevation of 5 feet above the ground surface. The stations are inspected from time to time by trained officials of the Weather Bureau, with a view to having the instrumental exposure and observational work in general as uniform as possible throughout the country. The records in most cases cover a period of at least 20 years, although some for shorter periods were used, particularly in the far Western States, where fewer long records are available.[1]

SOLAR AND PHYSICAL CLIMATE

The climate that would prevail if the earth had a homogeneous land surface and if there were no atmosphere is termed "solar climate." Under such conditions the amount of insolation received at any place would depend wholly on the declination of the sun, and all places of the same latitude would have similar temperature conditions. "Physical climate," or that actually prevailing, is a modification of "solar climate," produced by the presence of the atmosphere, the unequal distribution of land and water surfaces, differences in altitude, air movement, direction of ocean currents, and other causes. There are three major types of physical climate—marine, continental, and mountain. There are also several minor types, principal among which are those designated as "coast or littoral climate" and "desert climate."

Marine climate.—The marine type of climate is characterized by comparatively uniform temperatures throughout the year, and by small diurnal range in temperatures. Water surfaces under the influence of the sun's rays warm more slowly than land surfaces and cool more slowly in the absence of direct insolation. The temperature of the overlying air likewise changes slowly, and this results in a more uniform temperature condition than is found in other types of climate. The progress of the seasons is also retarded, winter lingering later into spring and summer into fall. Marine climates have, therefore, comparatively pleasant summers, mild winters, cool springs, and warm autumns.

Continental climate.—The continental type of climate is characterized by greater temperature extremes and more rapid changes in temperature. The coldest month in northern latitudes is usually January and the warmest is July, the time of maximum and minimum temperatures occurring earlier than in the marine type. The diurnal and annual ranges, as well as the irregular changes in temperature from day to day are large, and increase, as a rule, with increasing distance from the oceans. In the United States practically all districts east of the Rocky Mountains have this type of climate, even near the Atlantic coast, as the general atmospheric drift is offshore, which prevents the marine influence from being effective to any considerable distance inland. The annual march in temperature is shown for selected stations in Figures 1 and 72, and the diurnal in Figures 85 and 86. The characteristic increase both in the annual and diurnal temperature range with increasing distance inland may be noted in these figures.

Extreme types of continental climate are found in deserts. Here in the absence of vegetal covering, and with clear, dry air, the earth's surface heats very rapidly under direct insolation, and high day temperatures result. At night radiation of heat is rapid from the barren ground, as the dry atmosphere offers little obstruction to the passage of heat into space, and a rapid decrease in temperature results. Although the diurnal range in temperature in deserts is much greater than in other types of climate, the high day temperatures are not so oppressive as the readings of the thermometer would appear to indicate, owing to the extreme dryness of the atmosphere. During the heated hours of the day the difference in the indications of two thermometers, one having the bulb covered with freely evaporating water and the other uncovered, is very great. This difference is known in meteorology as the "depression of the wet-bulb temperature." Its magnitude gives some indication of the degree of physical discomfort experienced during the prevalence of high temperatures which, in general, varies inversely with the depression of the wet-bulb temperature. At Yuma, Ariz., the average daily maximum dry-bulb temperature for the month of July is about 106° F. and the wet-bulb temperature is 75° F., the average depression of the wet-bulb thermometer at the time of maximum temperature being about 31° F., whereas at Chicago the averages for the same period are about 80° and 69°, respectively, the average depression of the wet-bulb temperature being only 11°. So far as bodily comfort is concerned the high temperature at Yuma is greatly mitigated by the increased opportunity for evaporation. Over large areas in the Southwest this desert climate prevails, though not in such degree as at Yuma. The large diurnal temperature range in desert regions is shown in the section marked "Arid Plateau" in Figure 85 and also by the thermograph trace sheet for Yuma, Ariz., in Figure 87.

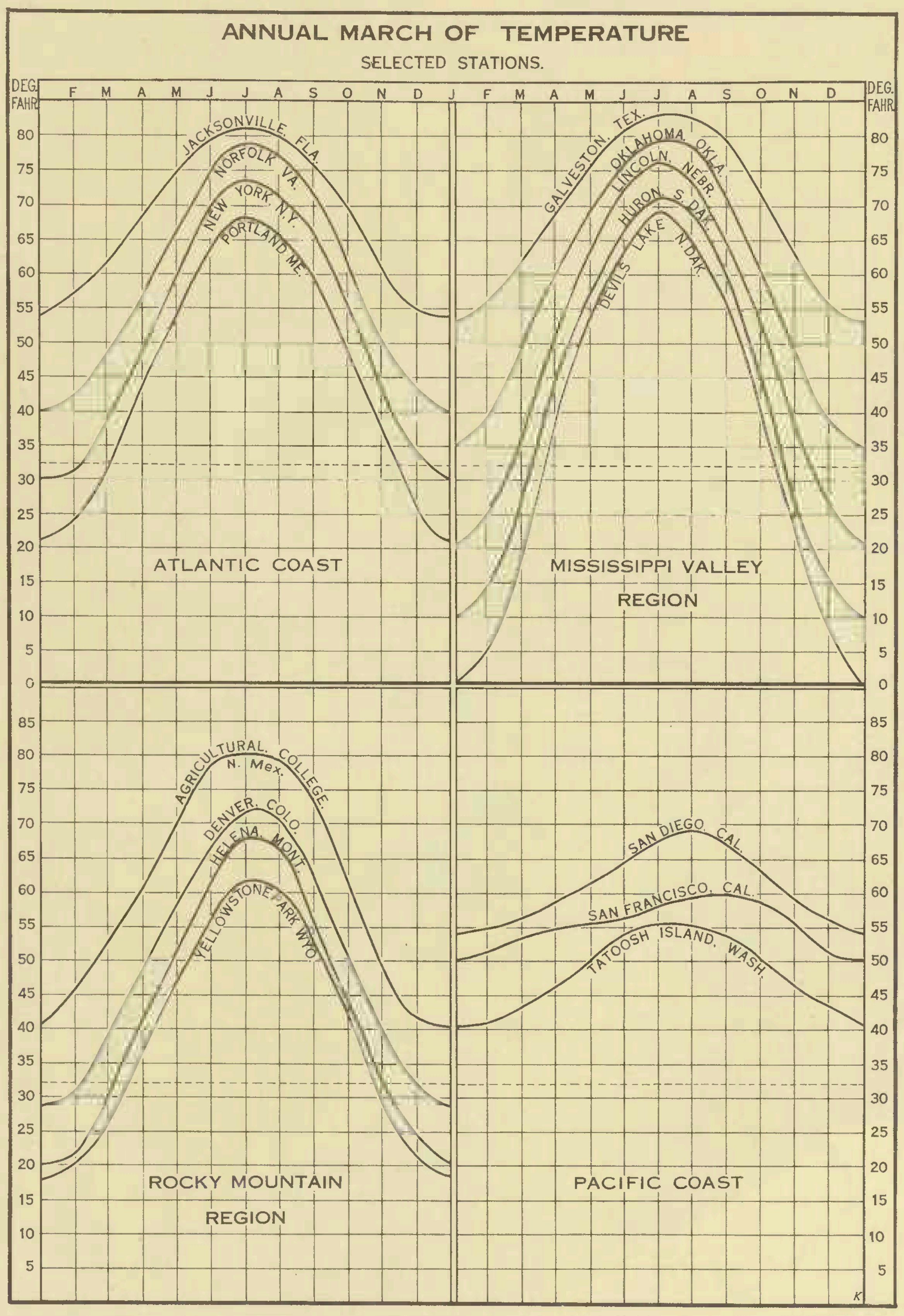


Figure 1.—This graph shows the annual march of temperature at selected stations, arranged in four belts, each extending north and south. It visualizes the monthly changes in temperature for different sections of the country and also the latitudinal gradient for the several seasons. East of the Rocky Mountains the decrease in winter temperature from south to north is large, especially in the Mississippi Valley, whereas in summer the decrease is moderate. The small seasonal changes in temperature characteristic of marine climates and the great seasonal differences in temperature typical of continental climates are graphically contrasted in the belts marked "Pacific coast" and "Mississippi Valley region"

In some cases coasts of large bodies of water have climates closely allied to the continental type and in others the marine characteristics dominate, depending on the surface drift of the atmosphere, whether from the land or the water. When this drift is on-shore the coast has a marine climate, as along the immediate Pacific coast of the United States. When the drift is off shore, a more or less modified form of continental type of climate obtains, which is exemplified along the Atlantic coast of the United States. On the Pacific coast the summers are cool, owing to the prevailing westerly winds, and the winters are mild for the same reason, while extremes in temperature are rare. However, this condition is confined to a narrow belt along the immediate coast, especially as regards cool summers, since mountain barriers prevent the extension of the marine influence to any considerable distance inland. The marine character of climate obtaining on the Pacific coast is shown by the graphs for San Francisco and North Head in Figures 1 and 85. In these graphs the small annual and diurnal temperature ranges may be noted. They show also the temperature ranges along the Atlantic coast, where the characteristics of the continental type predominate, although the marine influence is appreciable as compared with the central section of the country. Figure 1 also visualizes the temperature gradient from north to south in the United States for the several seasons of the year, separately for the Atlantic coast, the Mississippi Valley, the Rocky Mountain region, and the Pacific Coast States.

Mountain climate.—Mountain climate, as compared with that of the adjacent lowland, is characterized by lower temperatures throughout the year, but the diurnal and other variations are generally somewhat less than those experienced at lower elevations. The average decrease in temperature with increase in altitude in the free air is about 1° F. for each 330 feet, but the rate varies with the season of the year and is also much affected by local conditions. It is more rapid in summer than in winter and is greatest during the warmer hours of the day. Temperature inversions, which frequently occur during the colder months and especially at night, sometimes give to mountain slopes a higher temperature than is experienced in the near-by lower valleys. This condition is brought about by the air in contact with the mountain sides through the influence of surface radiation in the absence of direct insolation becoming colder than the free air over the valley and the increased weight, resulting from cooling and contraction, sets up a convectional circulation, or interchange of air between that near the surface of the colder mountain side and the warmer free air above the valley below. This circulation is continuous as long as the difference in air density is maintained. In such cases there is a much larger diurnal temperature range in the valley than on the mountain sides.

Under direct insolation surface soil temperatures in high altitudes become relatively higher than the adjacent air temperatures because the rarefied condition of the atmosphere and the comparatively small amount of aqueous vapor contained in it offer little obstruction to the passage of the sun's rays. These conditions, however, have a reverse effect at night by affording less resistance to radiation, and consequently there is a greater diurnal range in soil temperature on mountains than on lowlands.

IMPORTANT TEMPERATURE DATA

For the presentation of the climatic factors of any place the most important temperature data required are as follows: Average daily temperature; average daily range and average daily variability; average monthly temperature; average monthly range and absolute monthly extremes; seasonal temperature, especially the average summer (June, July, and August) and average winter (December, January, and February) temperature; average annual temperature and average annual range; and the frequency of occurrence and duration of certain significant temperatures.

Average daily temperature.—The true average daily temperature corresponds closely to the average of 24 hourly observations, but as several other combinations of hourly values give averages that differ but little from the true daily average some one of these is generally used to reduce observational work. The combination

$$\frac{(7\text{ a. m.}+2\text{ p. m.}+9\text{ p. m.}+9\text{ p. m.})}{4}$$

gives a value which differs only slightly from the true daily average, and

$$\frac{(\text{sunrise}+2\text{ p. m.}+9\text{ p. m.})}{3}$$

also gives fairly accurate results. The formula

$$\frac{(\text{maximum}+\text{minimum})}{2}$$

is easy of application and very satisfactory when dependable maximum and minimum thermometers are used and properly exposed. The mean of the daily extremes is, as a rule, slightly too high, but it usually does not vary more than one-half of a degree from the true daily average. This combination is employed by the Weather Bureau to obtain the average daily temperature, and the data for the accompanying charts and diagrams were compiled by its use.

Daily range and daily variability of temperature.—The normal diurnal march of temperature may be described

[1] The maps and graphs contained in this section of the Atlas were originally completed and ready for publication in 1917, but owing to the exigencies brought about by the World War publication could not be accomplished at that time. The original data embrace the 20-year period from 1895 to 1914, inclusive, corresponding to that covered by Section I, "Frost and the Growing Season," and by Section B, "Precipitation and Humidity," of this Atlas, both of which have already been published.

Since 1914 eight years of additional records have become available. These have been carefully examined and compared with the original data to determine what changes, if any, would be necessary, in order that the several maps and graphs should portray general conditions up to and including the year 1922.

The following maps have been fully revised to satisfy this requirement: Figures 3 6, 15, 16, 20, 25, 26, 30, 31, 36, 40, 41, 45, 46, 50, 51, 55, 56, 60, 61, 65, 66, 70, and 71. The graphs which were intended only to show certain characteristic variations in temperature in different portions of the country, such as Figure 4, were not revised. It was found that all other maps and graphs required practically no changes to represent conditions virtually up to the time of publication.

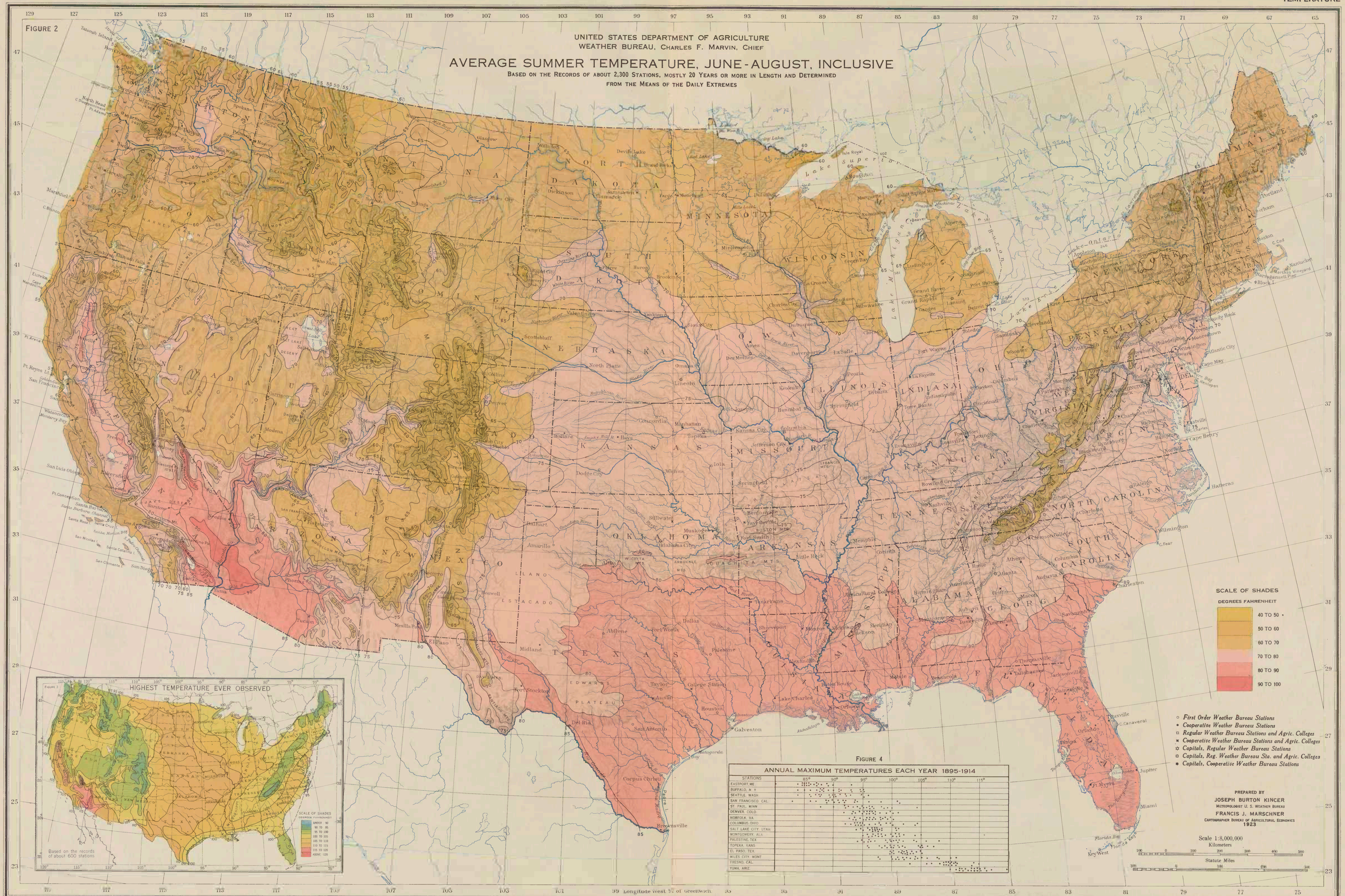


Figure 2.—This map shows the average summer temperature, June to August, inclusive. East of the semiarid Great Plains the crops grown and the types of farming are determined largely by the temperature of the summer season. In this area there are six more or less distinct agricultural regions, extending in a general way east and west belts. (1) The Subtropical Crops Belt, extending along the coast of the Gulf of Mexico and up the Atlantic coast as far as Charleston, S. C. In this region the characteristic crops are citrus fruits, winter vegetables, sugar cane, and rice, and the average summer temperature is 80° to 82° F. (2) The Cotton Belt, lying immediately to the northward, which has an average summer temperature decreasing from about 81° at the southern boundary to 77° at the northern. In this region cotton and corn are the dominant crops, constituting about three-fourths of the acreage of all crops. (3) To the northward of the Cotton Belt lies the Corn and Winter Wheat Belt, having an average summer temperature decreasing from 77° along the southern border to about 75° in the northern portion west of the Appalachian Mountains and 70° east of the mountains. In this region corn, wheat, tobacco, and hay are the most important crops, and diverse types of agriculture prevail. (4) The Corn Belt, which lies west of the Appalachian Mountains, and has a summer temperature of about 75° along the southern border and 69° along its northern border. Winter wheat supplements the corn crop in its southern portion and spring oats in its northern portion. Hay, mostly timothy and clover in the east and alfalfa in the west, is also an important crop. (5) The Spring Wheat Region, comprising western Minnesota, the Dakotas, and eastern Montana. The average summer temperature in this region decreases from about 69° at the southern boundary to 63° near the Canadian border, and 59° along its northern margin in Canada. Spring wheat, oats, barley, flax, and hay are the important crops. (6) The Hay and Pasture Region, comprising the northern border States from Minnesota eastward and extending southward along the Appalachians. This region, in which hay and pasture constitute over 50 per cent of the improved land, has an average summer temperature ranging from about 59° to 70°. With reference to temperature conditions the Spring Wheat Region is only a subhumid grass land extention of the originally forested Hay and Pasture Region lying to the east, while the Corn Belt is really a large and extraordinarily fertile portion of the Corn and Winter Wheat Belt

Figure 3 shows the highest temperatures ever observed, based on the records of the regular reporting and of selected cooperative stations up to and including the year 1922. Temperatures over 100° F. have been experienced in all portions of the country, except in the higher altitudes of the Rocky Mountain and Appalachian areas, the central and northern portions of both the Pacific and Atlantic coasts, portions of New England, and in the Florida Peninsula

Figure 4 shows for selected stations the maximum temperature for each of the 20 years from 1895 to 1914, inclusive. Each dot represents the highest temperature recorded for an individual year, there being 20 dots for each station

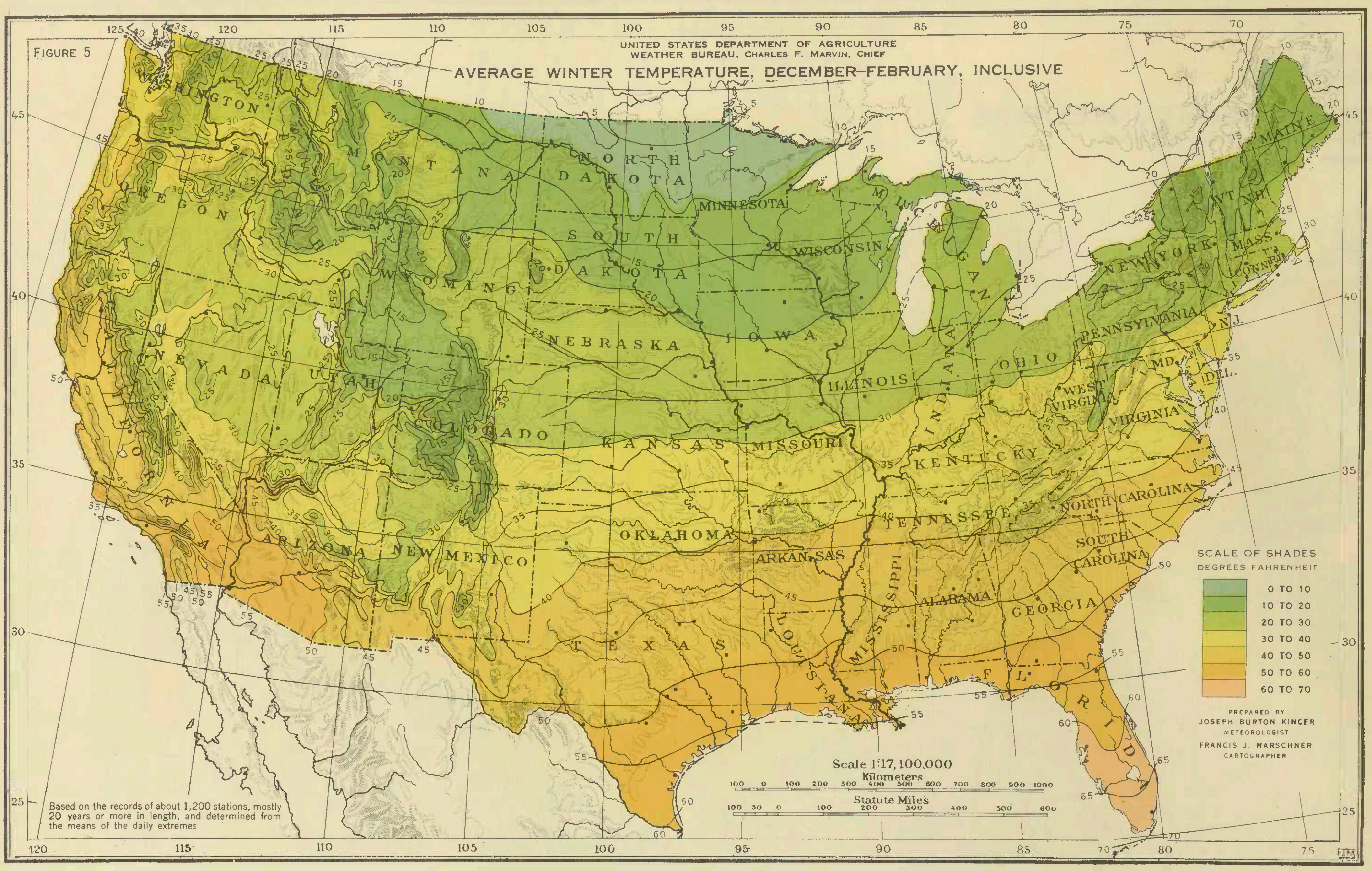


Figure 5.—This map shows the average winter temperature, December to February, inclusive. East of the Rocky Mountains the average winter temperature increases from near zero in northwestern Minnesota and northeastern North Dakota to about 32° F. in central New Jersey, southern Ohio, and the central portions of Missouri and Kansas, and to about 55° along the Gulf coast. To the westward it ranges from somewhat less than 15° at the higher altitudes of the Rocky Mountain region to about 55° in the lower Colorado River Valley and along the coast of southern California. The Subtropical Crops Belt has an average winter temperature ranging from about 50° in the rice district of Louisiana to 70° in extreme southern Florida. In the Cotton Belt it ranges from 40° to 50°, and even 55° in southern Texas; in the Corn and Winter Wheat Belt from about 30° along the northern border of the belt to about 40° in the southern; in the Corn Belt from 15° in southwestern Minnesota to about 30° along the southern margin, and in the Spring Wheat Belt it varies from near zero to about 15°. In the Hay and Pasture province the average winter temperature varies widely. It is about zero in northeastern Minnesota and reaches 35° locally in the central Appalachian valleys

briefly as follows: In continental climates the daily minimum usually occurs about the time of sunrise, and in marine climates somewhat earlier. Beginning at this time there is a gradual increase until the maximum is reached, usually from two to four hours after noon in the continental type of climate and about noon, or shortly after, in the marine type. From the time of the maximum there is a gradual decrease until the next morning when the minimum is again reached. Figure 85 shows for selected stations, representing the Atlantic and Gulf coasts, the Mississippi Valley, the Rocky Mountain region, the Arid Plateau, and the Pacific coast, the diurnal march of temperature for the months of January, April, July, and October. This graph shows the characteristic features of the normal daily temperature curve for the principal climatic divisions of the United States. The significance of the average daily temperature for a locality depends on the amplitude of the periodic daily range and also on the nature of the nonperiodic or accidental changes that occur from day to day, or the daily variability. For example, the average daily temperature for August at San Diego, Calif., and at Bismarck, N. Dak., is about 68° F., but at Bismarck the average daily maximum is 81° as compared with 73° for San Diego, whereas the average daily minimum is 55° at Bismarck and 62° at San Diego. Thus while the average temperature at the two places for this month is the same, Bismarck has an average daily range of 26° and San Diego only 11°, which makes a marked difference in the actual temperature experienced. Again, the average temperature for a given month may be the same at two different places, and one may be subject to large daily variability, as shown by the difference between the mean temperatures for successive days, and the other may have comparatively uniform temperatures from day to day. Under such conditions, although the average monthly temperatures would be similar, the temperature conditions actually experienced would be wholly different. The daily variability of temperature is least in the marine type of climate and greatest in the continental type, increasing, as a rule, toward the center of continents. It is also greater in winter than in summer, owing to the more pronounced cyclonic and anticyclonic action during the winter. Figure 72 shows for each month of the year the average daily temperature range for selected stations in different sections of the United States, and the auxiliary charts accompanying the average monthly temperature charts show the average daily maximum and average daily minimum temperatures each month. Figures 81–84 show the average daily range in temperature throughout the United States for the months of January, April, July, and October; and Figure 86 shows for selected stations, representing the principal types of climate found in this country, the maximum and minimum temperatures each day for the years 1913 and 1914. In this graph the tops of the vertical bars show the daily maxima and the bottoms of the bars the daily minima. The length of the bars indicates the amplitude of the daily range, and their centers show the daily mean values. The relative position of the bars for successive days indicates the daily variability. This graph shows the characteristics of important temperature data for different sections of the country and for the several seasons of the year in such manner as to facilitate comparison of conditions in different localities.

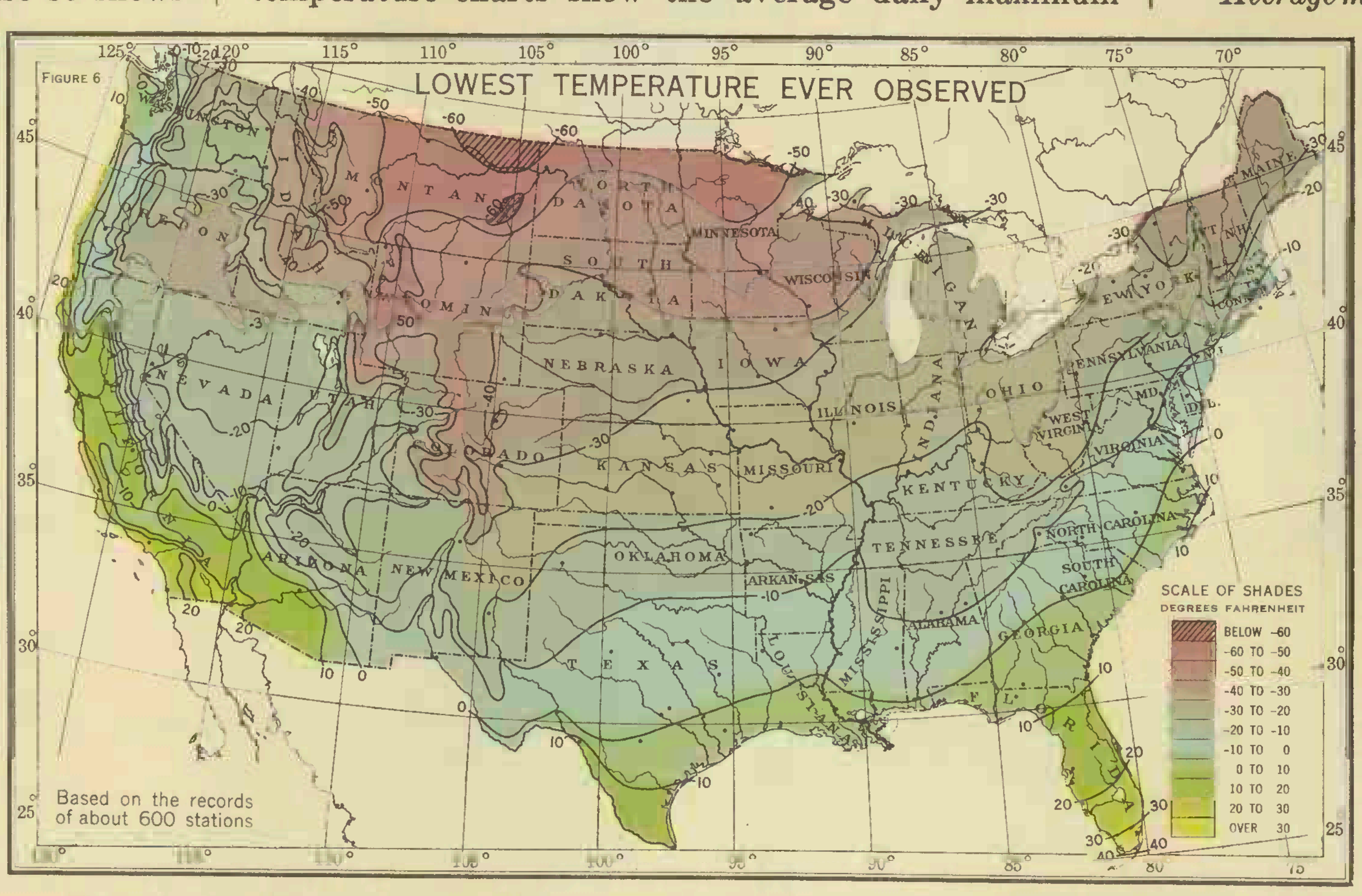


Figure 6.—This map shows the lowest temperatures ever observed up to and including the year 1922, based on the records of the regular reporting and of selected cooperative stations. These absolute minimum temperatures range from −65° F. in eastern Montana to 41° at Key West, Fla. Temperatures of −40° have been recorded in northern New England and northern New York, and as low as −20° as far south as Tennessee, Arkansas, and Oklahoma, and zero temperatures have occurred in the central Gulf coast districts. Along the central and southern California coast the lowest temperatures of record are from 24° to 28°

Average monthly temperature and monthly extremes.—The average of the daily temperatures of a month is known as the average monthly temperature, and its significance depends on the extent of the periodic variations in the daily values, from which it is derived, and on the frequency and amount of the nonperiodic or accidental fluctuations that are liable to occur from time to time during the month. Figures 12, 17, 22, 27, 32, 37, 42, 47, 52, 57, 62, and 67 show the average temperatures for each month of the year, based on the records of about 1,200 stations, which in most cases cover a period of at least 20 years. Accompanying these are auxiliary charts showing for each month the average daily maximum and the average daily minimum temperatures, and others showing the highest and the lowest mean monthly temperature observed during the 28-year period 1895 to 1922, inclusive.

In addition to the average of the daily maxima and the average of the daily minima it is important to know the average of the monthly extremes, that is, the average of the highest temperatures and the average of the lowest temperatures recorded each month, for a long series of years, and the absolute maximum and absolute minimum for each month. These data are shown for a considerable number of representative stations by the large graph-chart (fig. 72). These graphs show for the stations named, and for each month of the year, (1) the average monthly temperatures, (2) the average of the daily maxima and of the daily minima, (3) the average of the monthly maxima and of the monthly minima, and (4) the absolute maximum and absolute minimum,

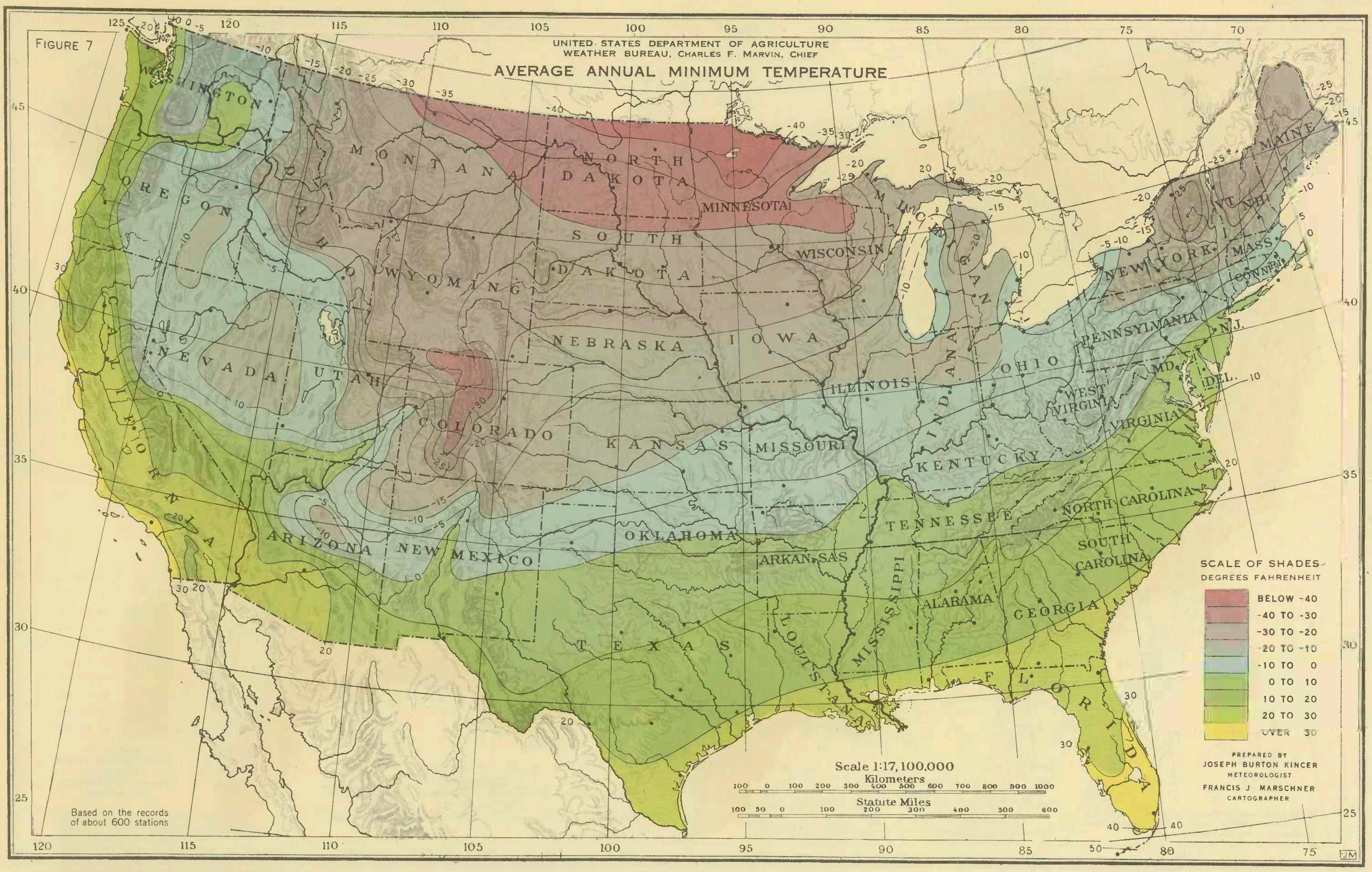
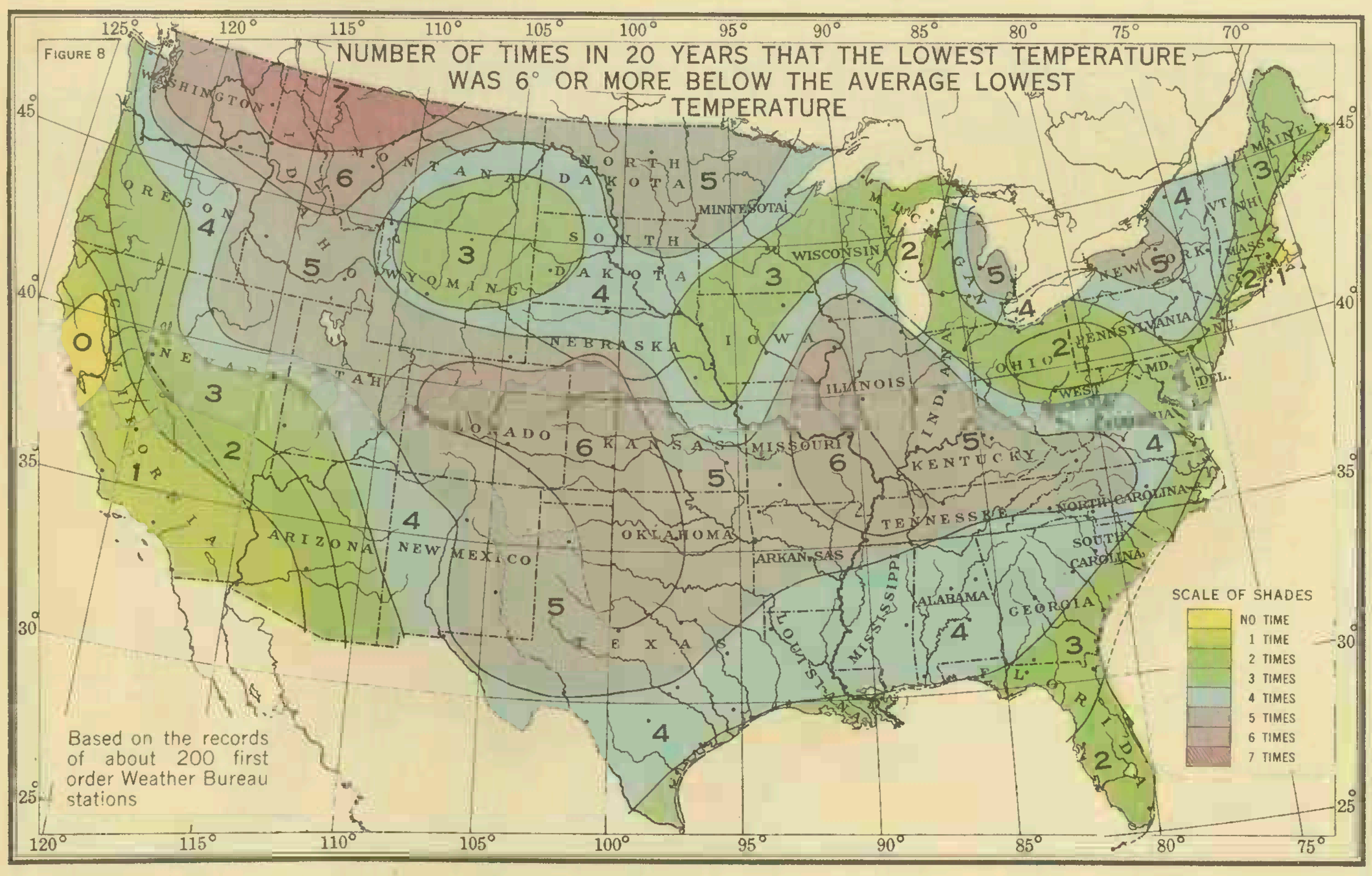
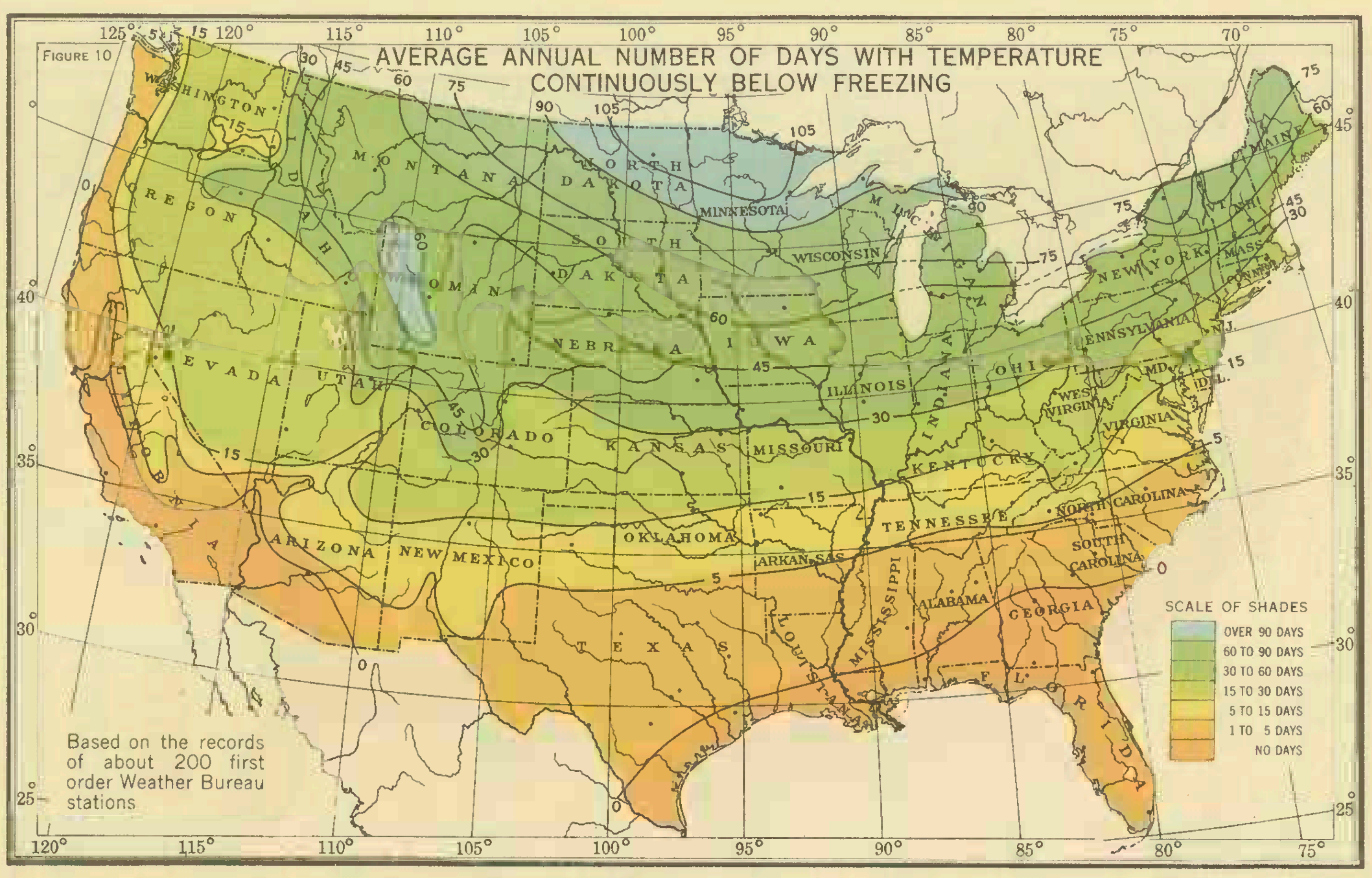
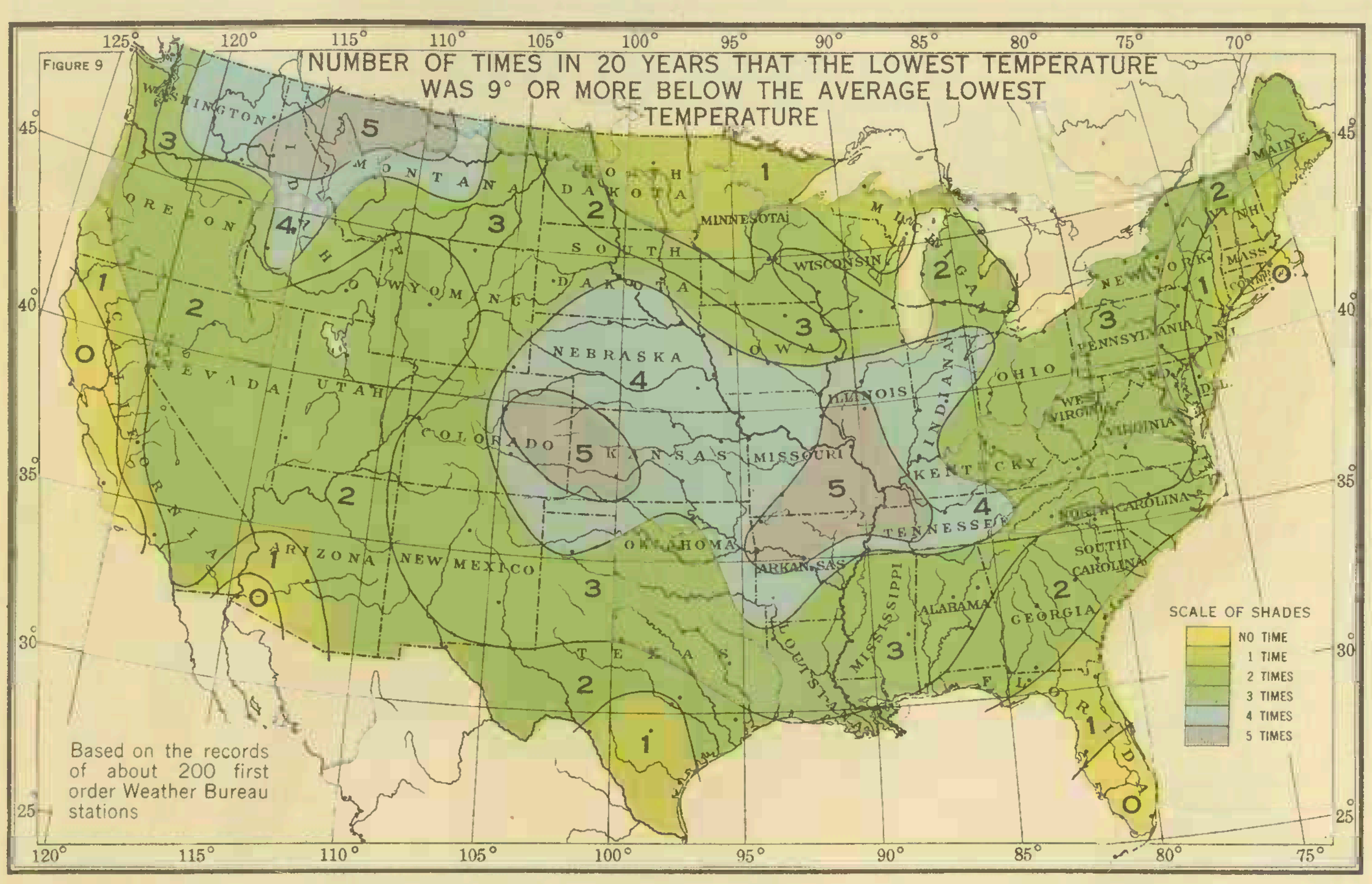
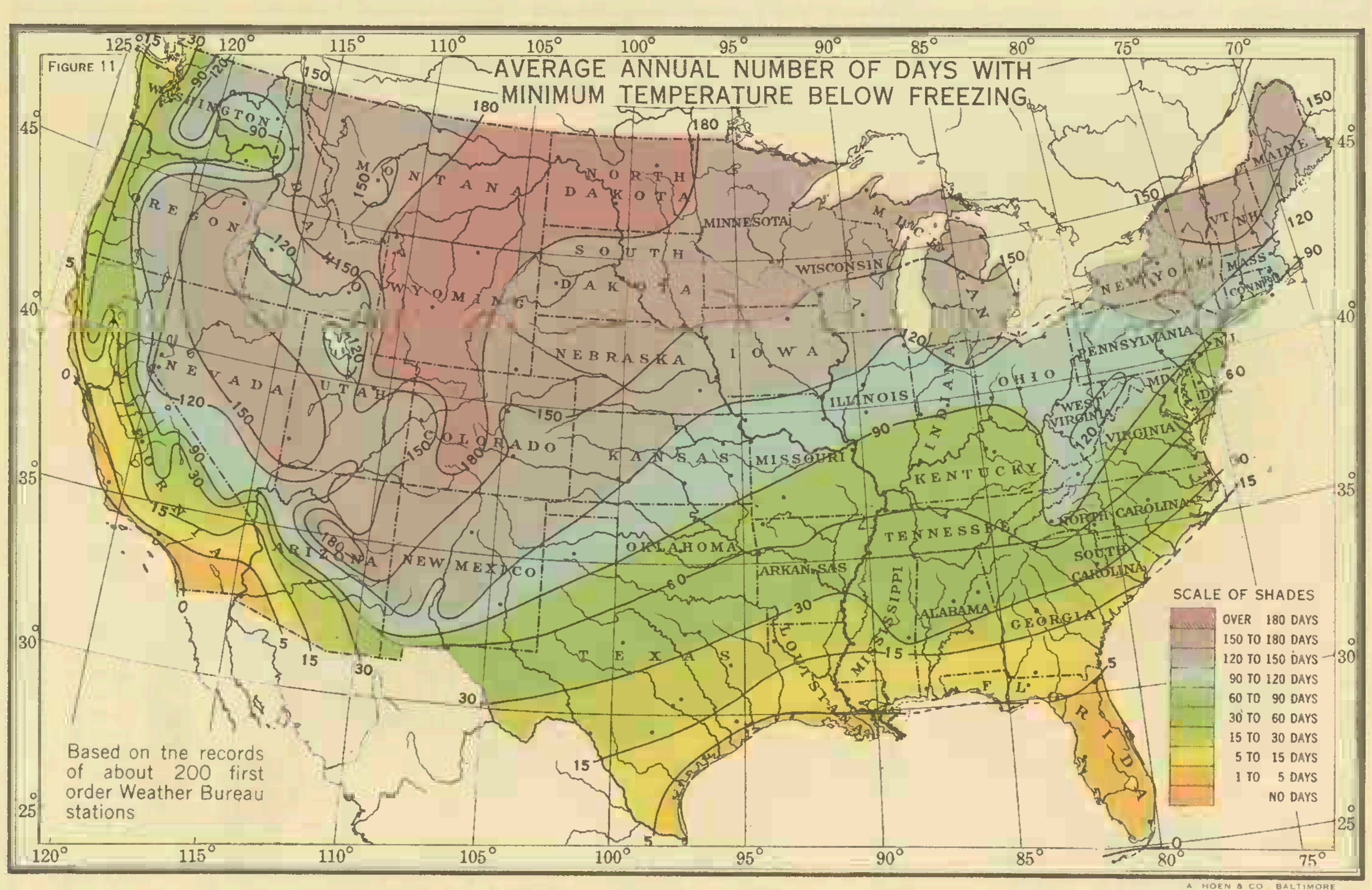


Figure 7.—This map shows the average of the lowest temperatures recorded each winter. As a rule, the lowest temperatures in the United States occur in the northern portions of North Dakota and Minnesota, usually about —40° F. or slightly lower. The other extreme is found at Key West, Fla., where the lowest temperature for the year ordinarily does not go below 50°. Along the immediate Gulf coast the average annual minimum is 22° to 25°, whereas along the immediate Pacific coast it ranges from about 25° at the north to 36° at the south. The marine influence is markedly shown by the north and south trend of the isotherms along the Pacific coast, and is noticeable along the Atlantic coast, where the isothermal lines trend in a northeasterly direction as they approach the ocean and terminate at the coast several hundred miles farther north than the latitude at which they cross the Mississippi Valley. The tempering effect of the Great Lakes is shown by the trend of the isotherms along their leeward shores in Michigan, Ohio, and New York









A. HOEN & CO. BALTIMORE

Figures 8 and 9 show the number of years in the 20-year period, 1895–1914, that the minimum temperature was 6° or more, and 9° F. or more, respectively, below the average annual minimum. These maps show the frequency of significant negative departures from the average annual minimum temperature. (Fig. 7)

Figure 10 shows the average annual number of days with minimum temperature at freezing, or lower. In portions of the northern Plains States and in the northern Rocky Mountain districts freezing temperatures usually occur on 180 to 200 days of the year, and in northern New York and northern New England on 165 days or more. To the southward there is a rapid decrease in number to about 5 days along the Gulf coast, whereas along the southern Pacific coast the average is less than 1 day annually.

Figure 11 shows the average annual number of days with temperature continuously below freezing during the day. In the northern portions of Minnesota and North Dakota there are, on the average, more than 100 days each year when the temperature does not rise above 32° F., but southward there is a rapid decrease to less than 1 day along the Gulf coast. Along the Pacific coast, except at the extreme north, the average is also less than 1 day.

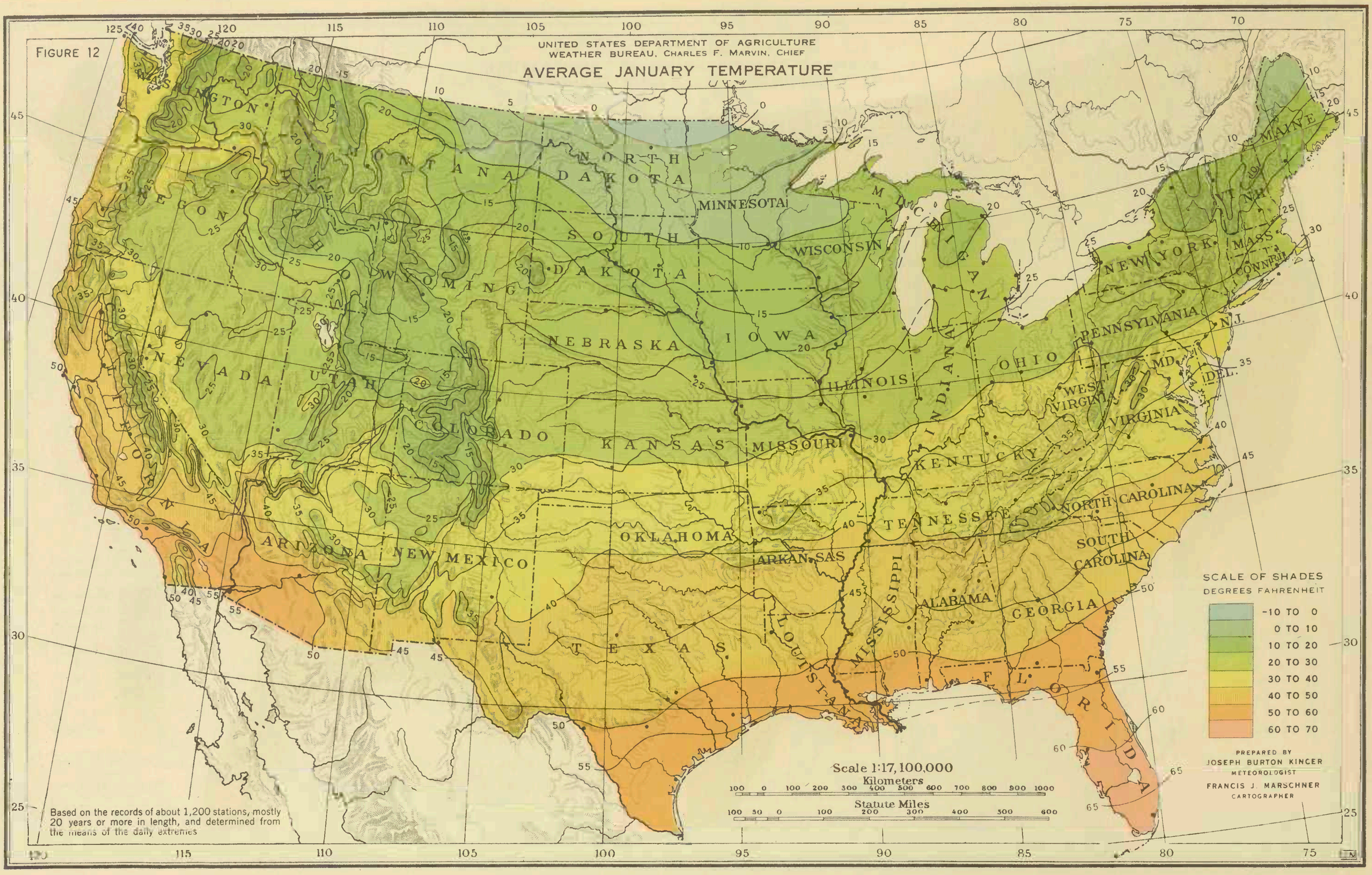
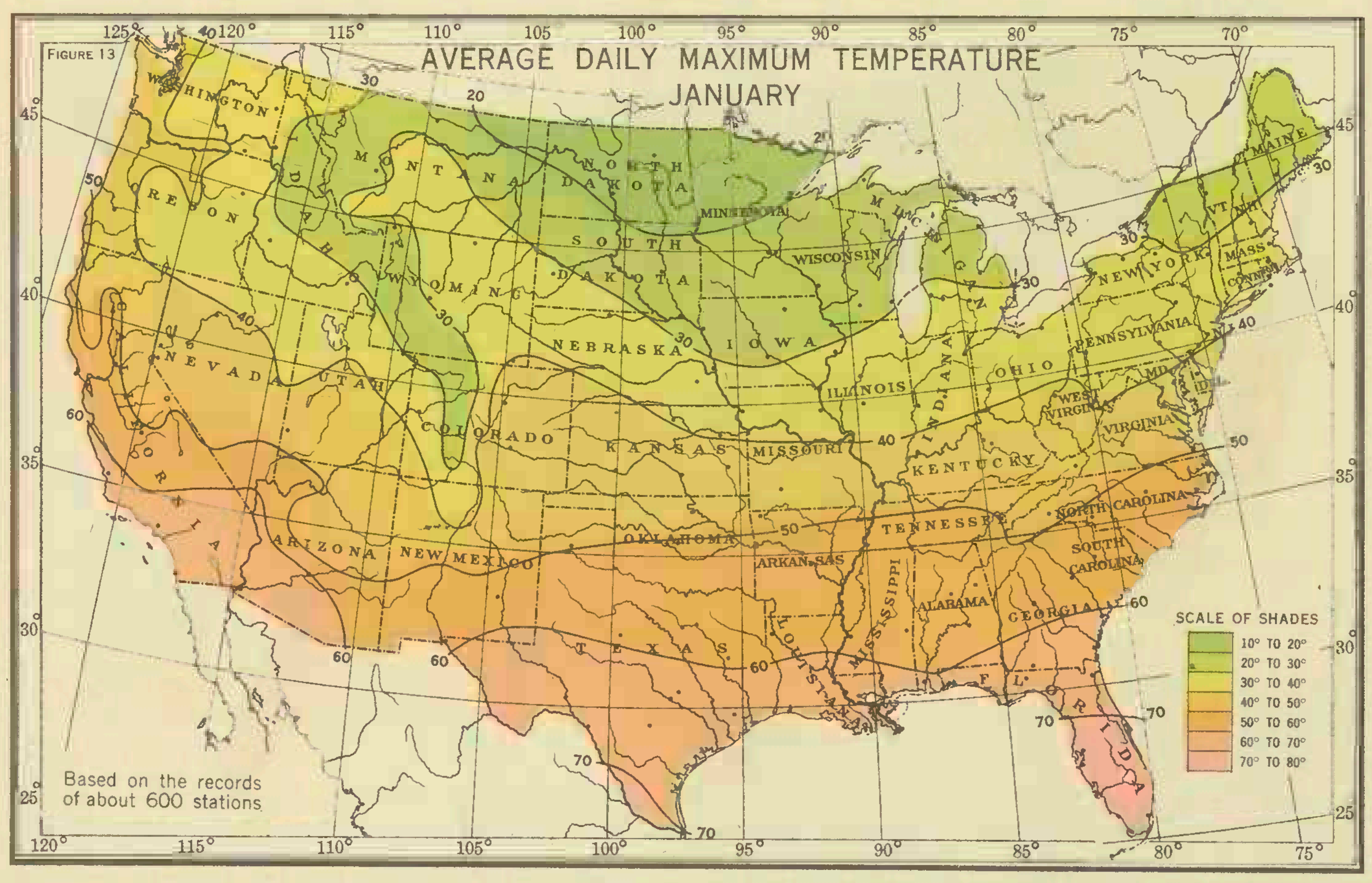
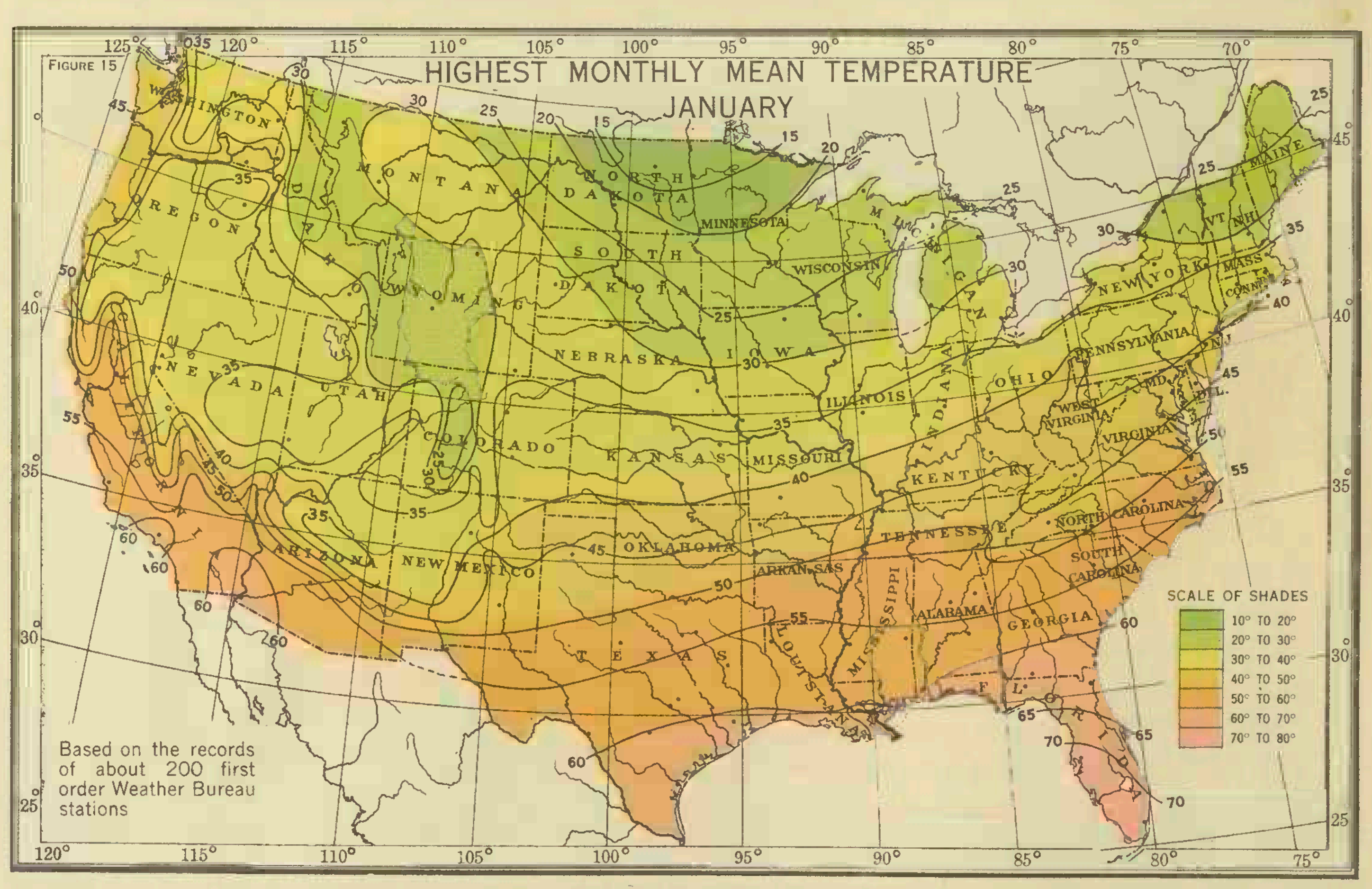
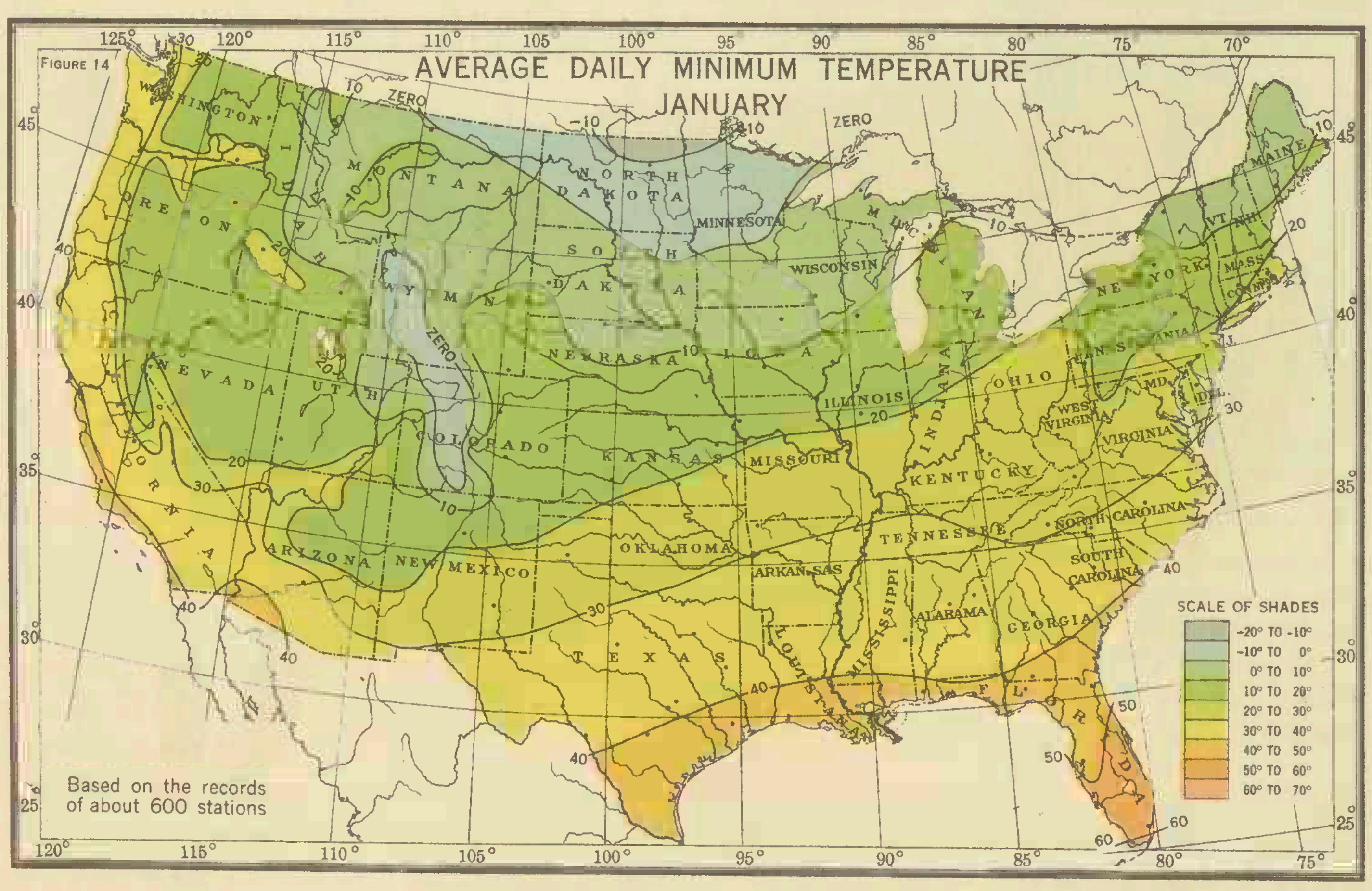
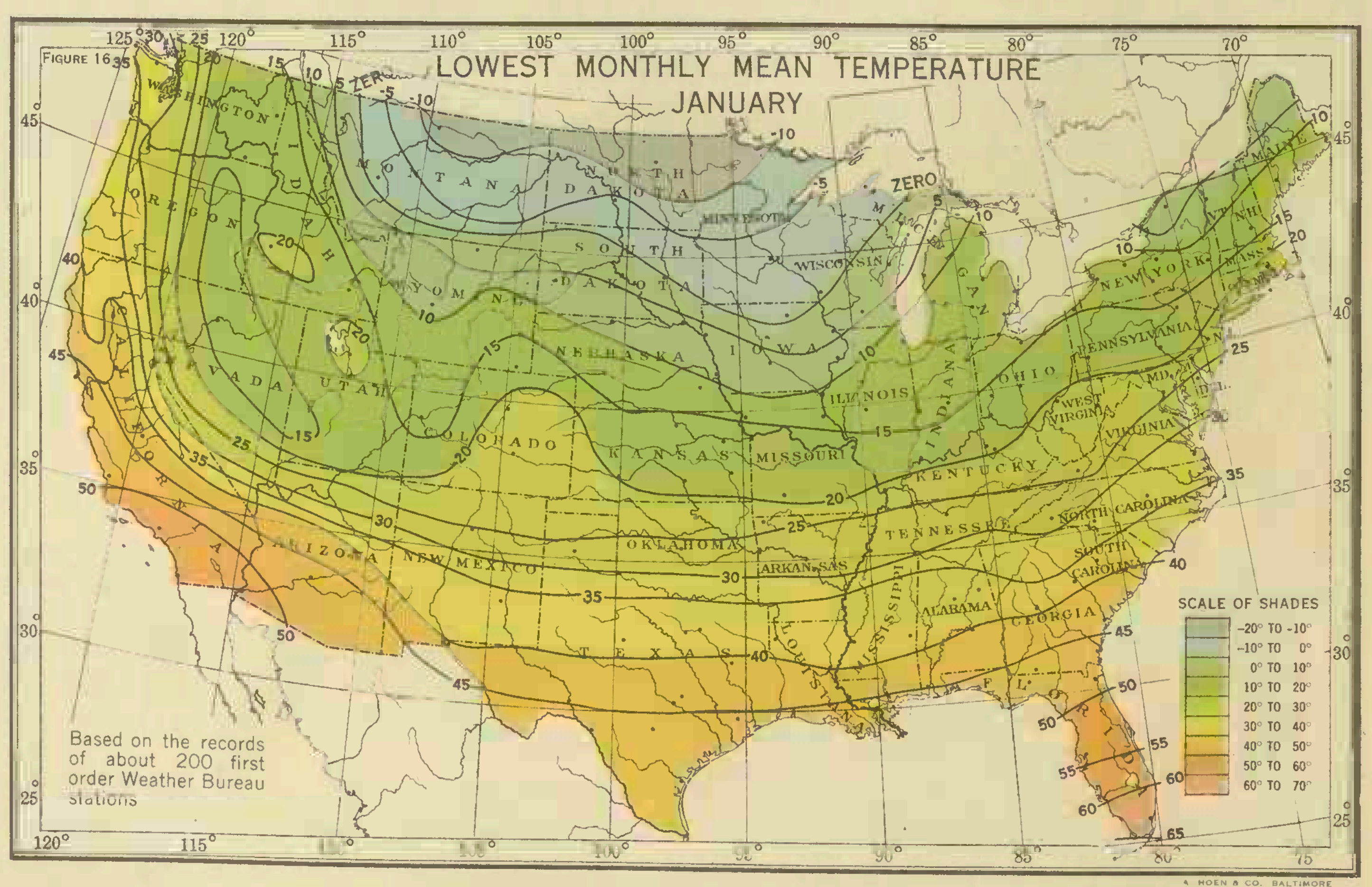


Figure 12.—January is, as a rule, the coldest month of the year. The lowest temperatures usually occur in the northern portion of Minnesota and North Dakota, where the average temperature for the month is near zero. The temperature gradient from north to south is much more rapid in winter than in summer, the average January temperature increasing to about 55° F. at the coast of the Gulf of Mexico, an increase on the average of 1° for each 25 miles. In July the average increase in temperature from North Dakota to the Gulf coast is 1° for each 90 miles. (See fig. 42.) Throughout the interior of the continent temperature changes during January are frequent and often abrupt. Very cold weather is sometimes experienced in the northern interior districts in this month, temperatures as low as −40° to −50° being recorded occasionally in northern Minnesota, North Dakota, and eastern Montana, and records of −25° to −35° have been made in northern New York and New England. Along the Gulf coast the lowest recorded temperatures for this month range from 11° to 15°. Freezing temperatures are of infrequent occurrence in southern Florida and also along the coast of southern California









Figures 13 and 14 show for January the average daily maximum and the average daily minimum temperatures. In northern North Dakota the average daily temperature range in January is about 25° F. (see fig. 81), the average daily maximum being somewhat less than 20° and the average daily minimum −5° to −10°. To the southward there is a rather uniform increase in both these values, the average maximum reaching 60° to 70° and the minimum 40° to 50° along the Gulf coast. From the Rocky Mountains westward the average daily maximum for this month varies from 25° and 30° in the central and northern Rocky Mountain districts to about 65° along the southern California coast, and the minimum varies from nearly—10° in the central Rocky Mountain districts to about 45° along the coast of central and southern California

Figures 15 and 16 show the highest and the lowest mean January temperatures that occurred in the 28-year period 1895–1922. The variation in these temperatures is large in most districts, particularly in the north-central border States, where the mean January temperature one year may be as much as 20° or 25° F. warmer than in another year. Along the Pacific coast this variation is less than 10°

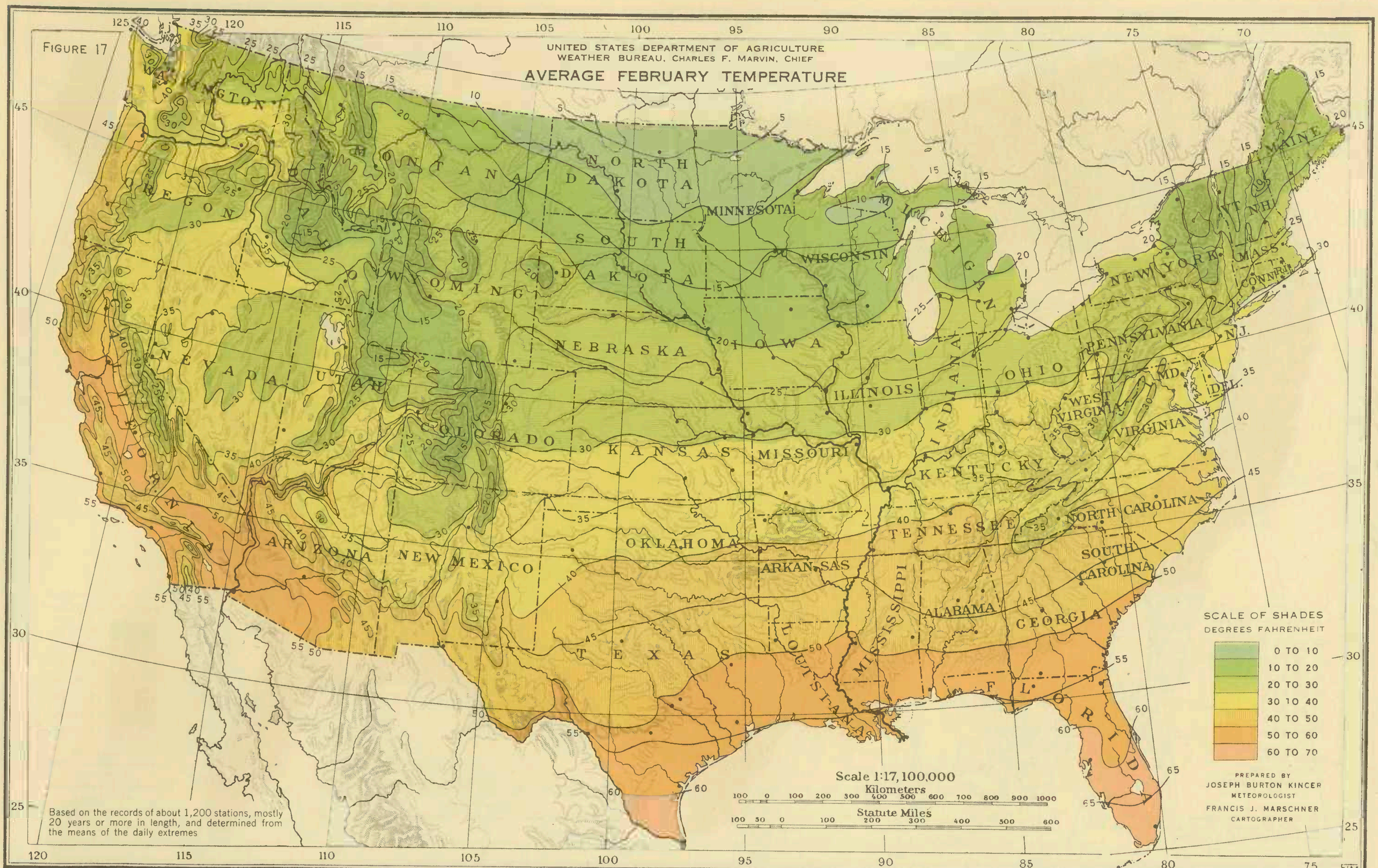
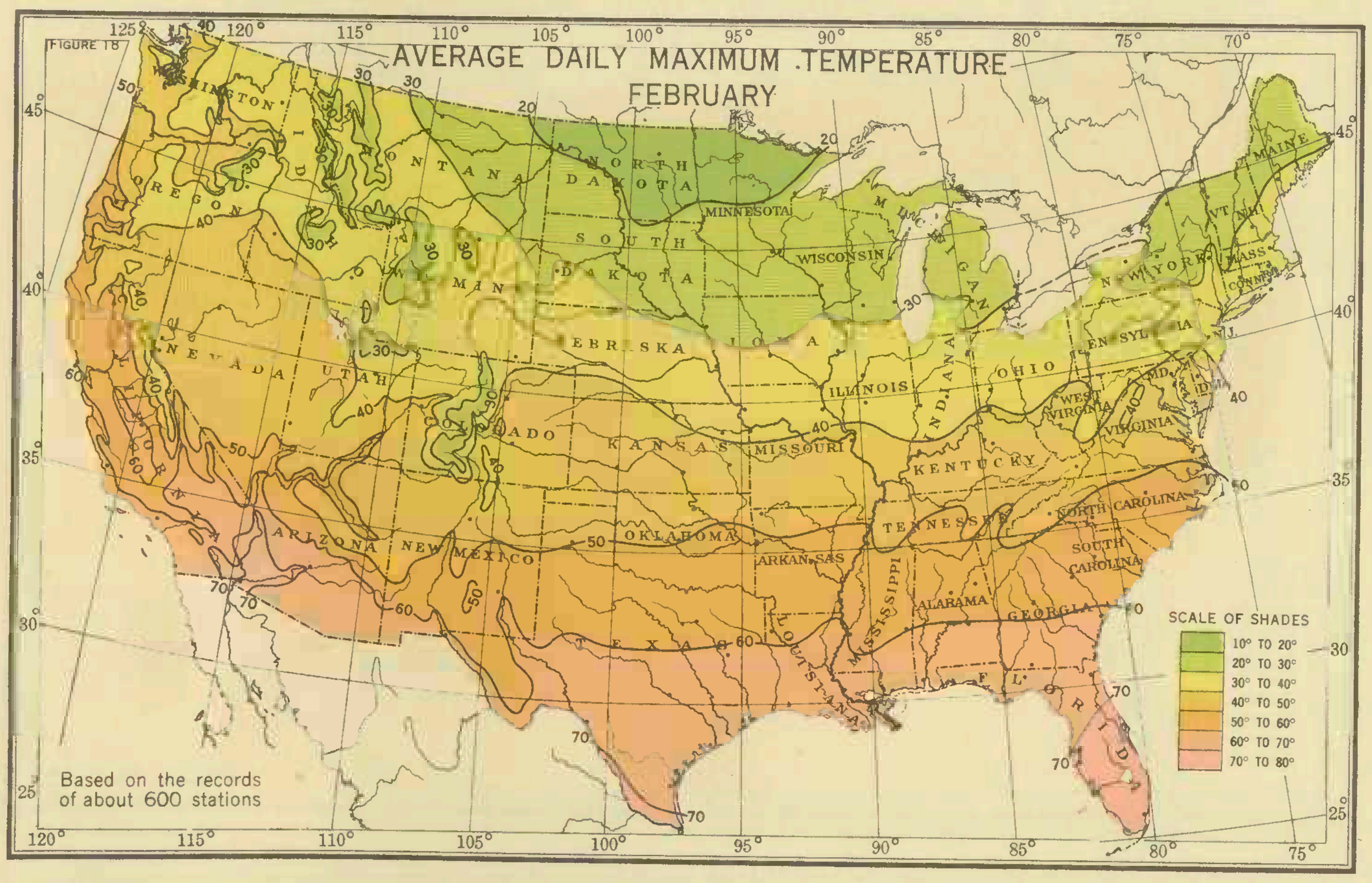
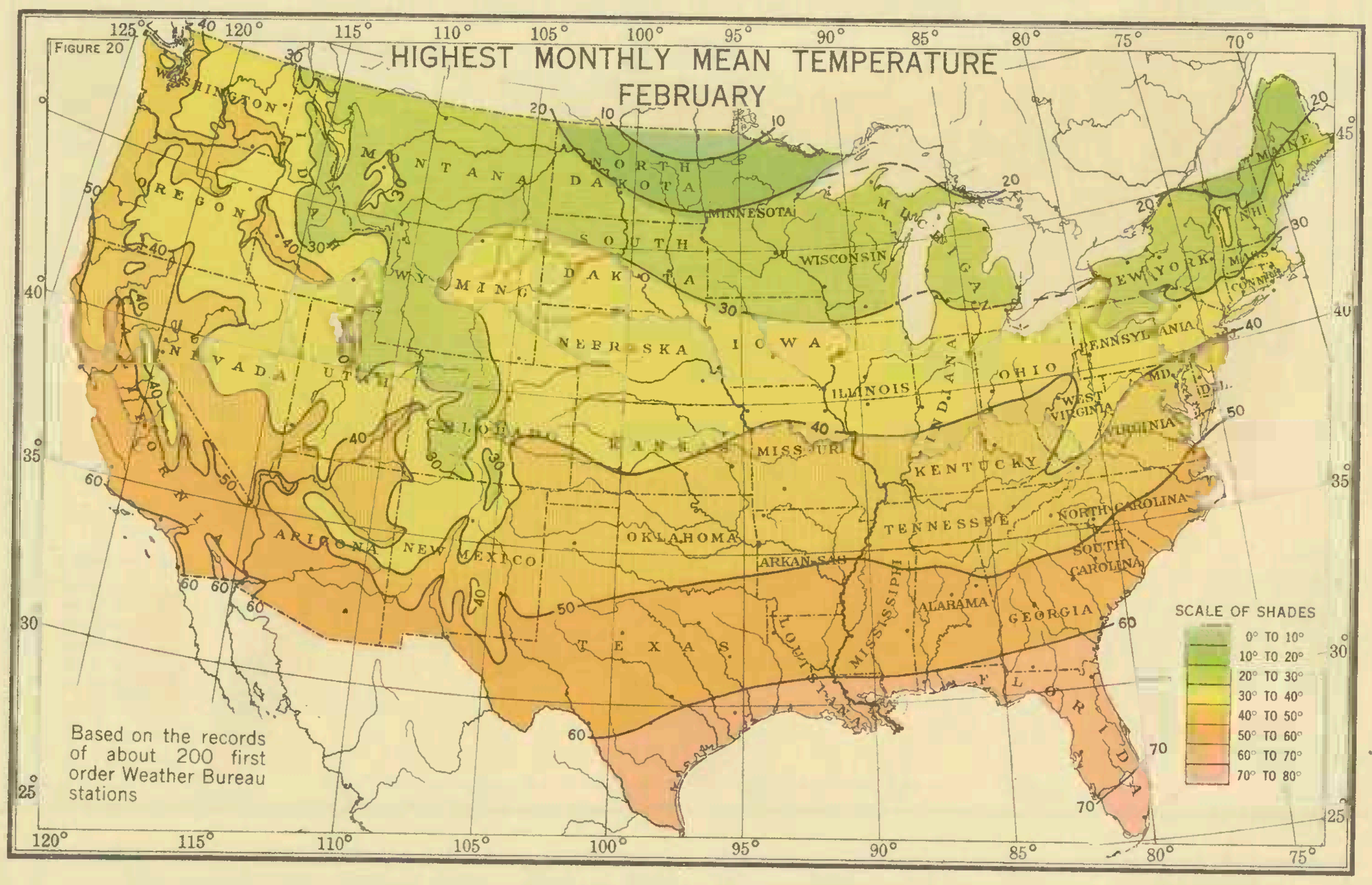
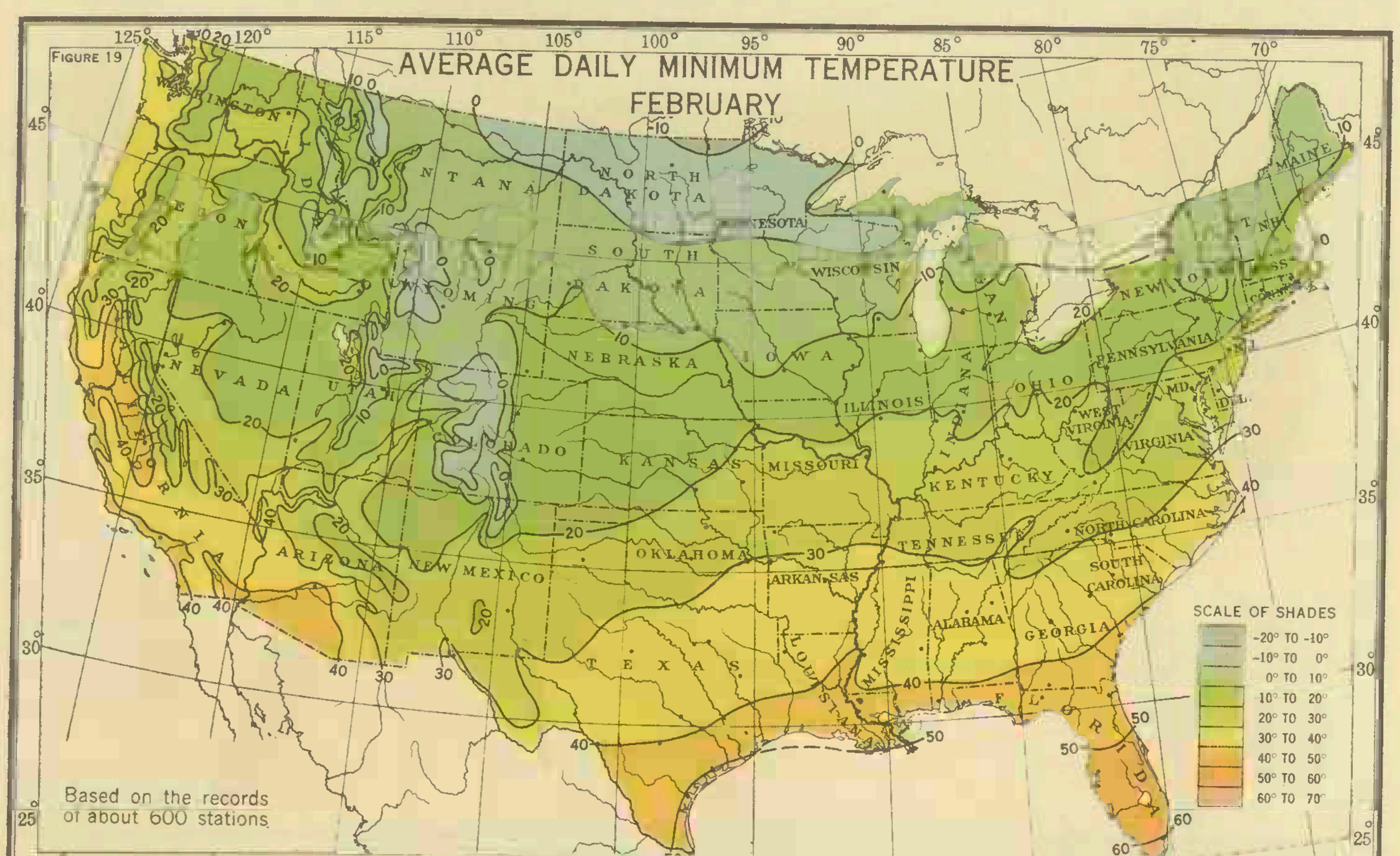
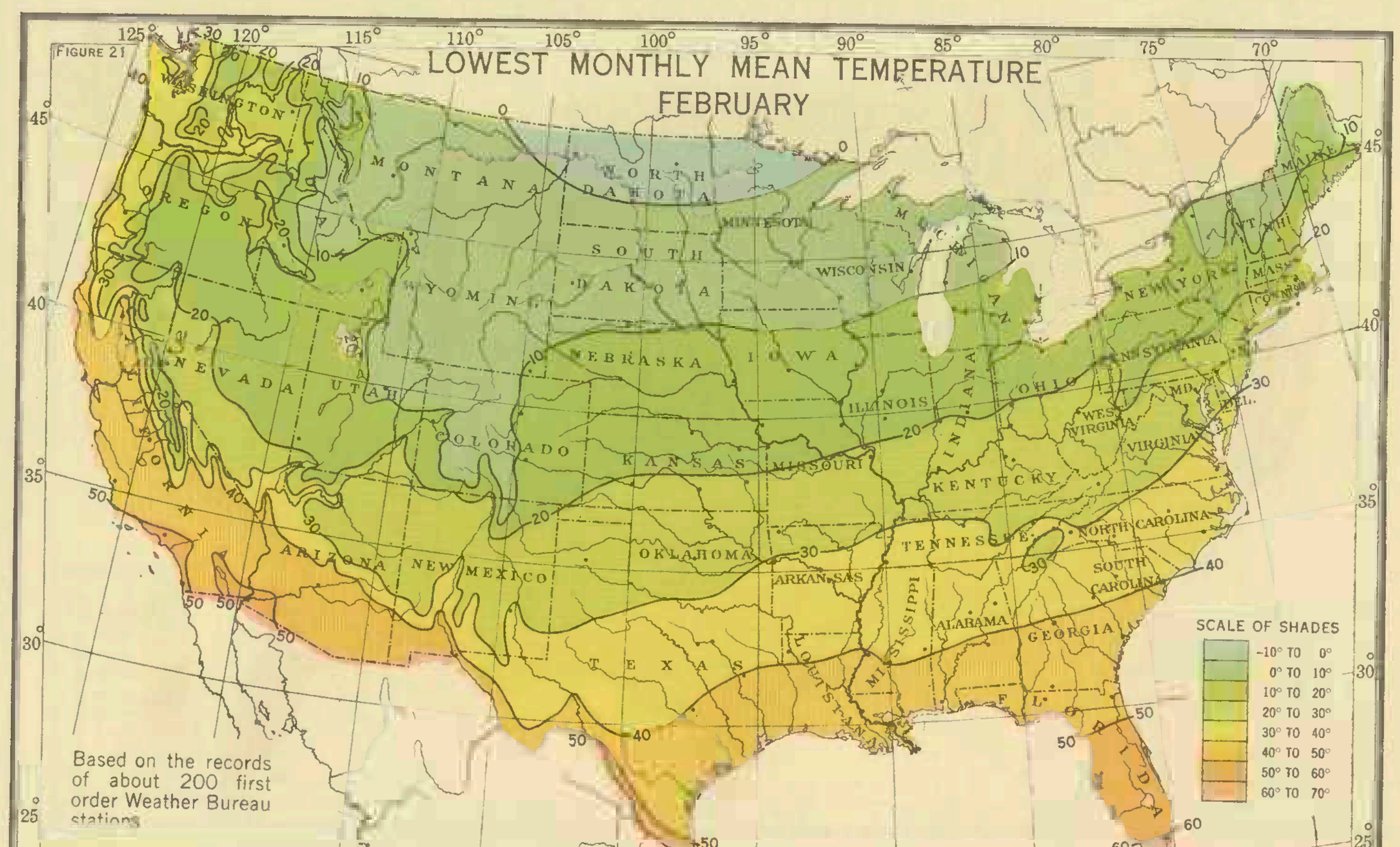


Figure 17.—The average temperature in February does not differ materially from that of January, but as a rule February is slightly the warmer month. The lowest average temperature for this month, about 5° F. is found in the northern portions of Minnesota and North Dakota. Along the Canadian border to the eastward it is about 10° higher. To the southward there is a progressive increase to about 55° along the Gulf coast. Cold waves continue to be of comparatively frequent occurrence in February, usually entering the United States from the Canadian Northwest and sometimes overspreading practically all the country east of the Rocky Mountains. In fact, the coldest weather of the year frequently occurs during the early part of this month. Temperatures as low as −25° have occurred in February as far south as Kansas and Missouri and records as low as 0° have been made in the central Gulf coast. However, there is usually an appreciable increase in temperature in the latter part of February, freezing weather, as a rule, not occurring along the immediate Gulf coast after the 20th of the month









Figures 18 and 19 show for February the average daily maximum and the average daily minimum temperatures. East of the Rocky Mountains the average daily maximum for this month ranges from about 15° F. on the Canadian border in Minnesota and North Dakota to about 65° along the Gulf coast, increasing to 75° at Key West, Fla. In the West the average daily maximum varies from about 30° in the central Rocky Mountain districts to nearly 75° in the lower Colorado River Valley. The average daily minimum east of the Rockies ranges from −10° at the Canadian boundary in the Red River Valley to 45° or 50° along the Gulf coast. In the West the average minimum varies from about −5° in the central Rocky Mountain districts to about 45° along the central and southern coast of California and in the lower Colorado River Valley

Figures 20 and 21 show the highest and the lowest mean February temperatures in the 28-year period 1895–1922. These mean temperatures do not differ materially, except in the more northern districts, from those for January

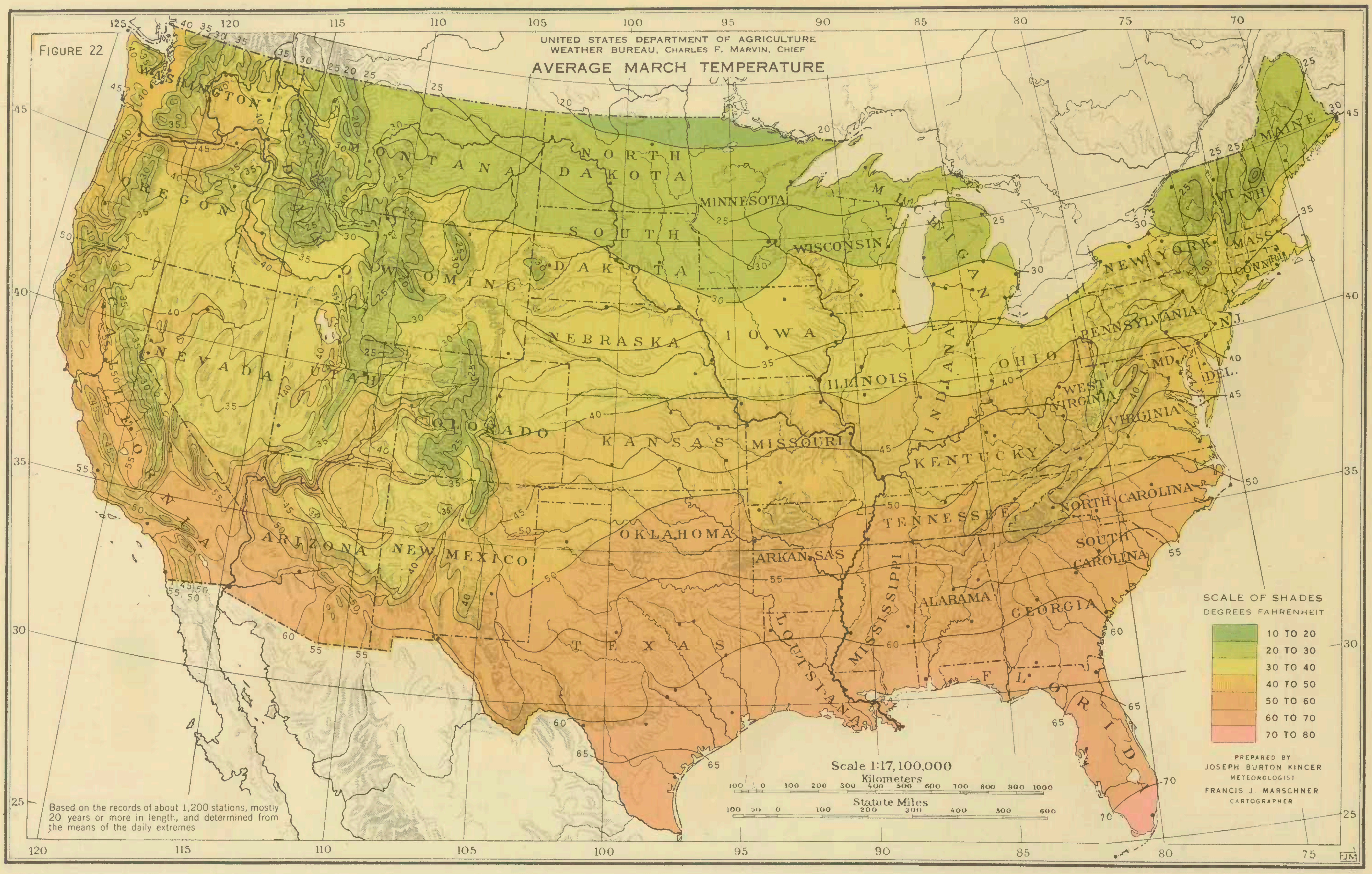
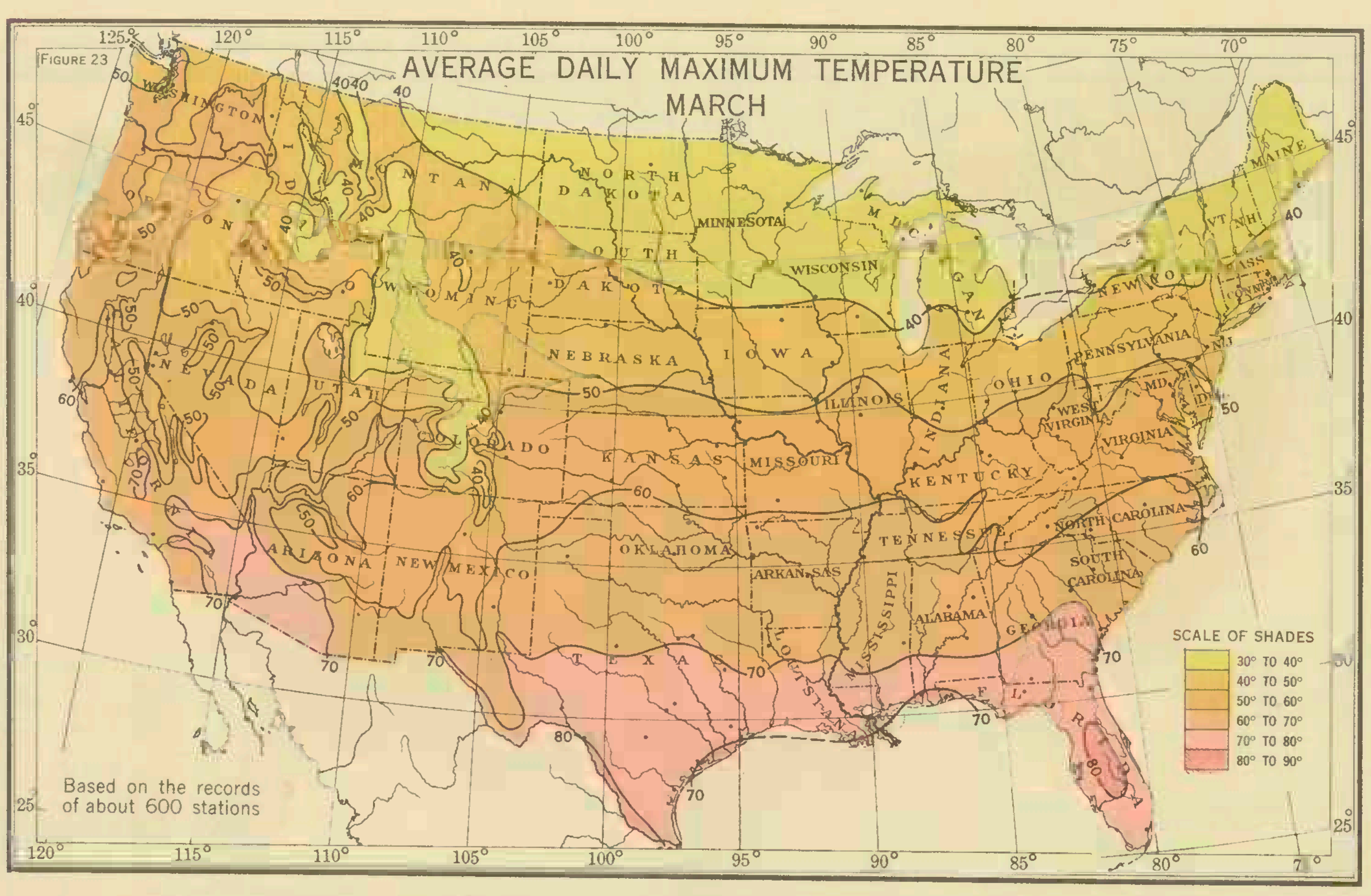
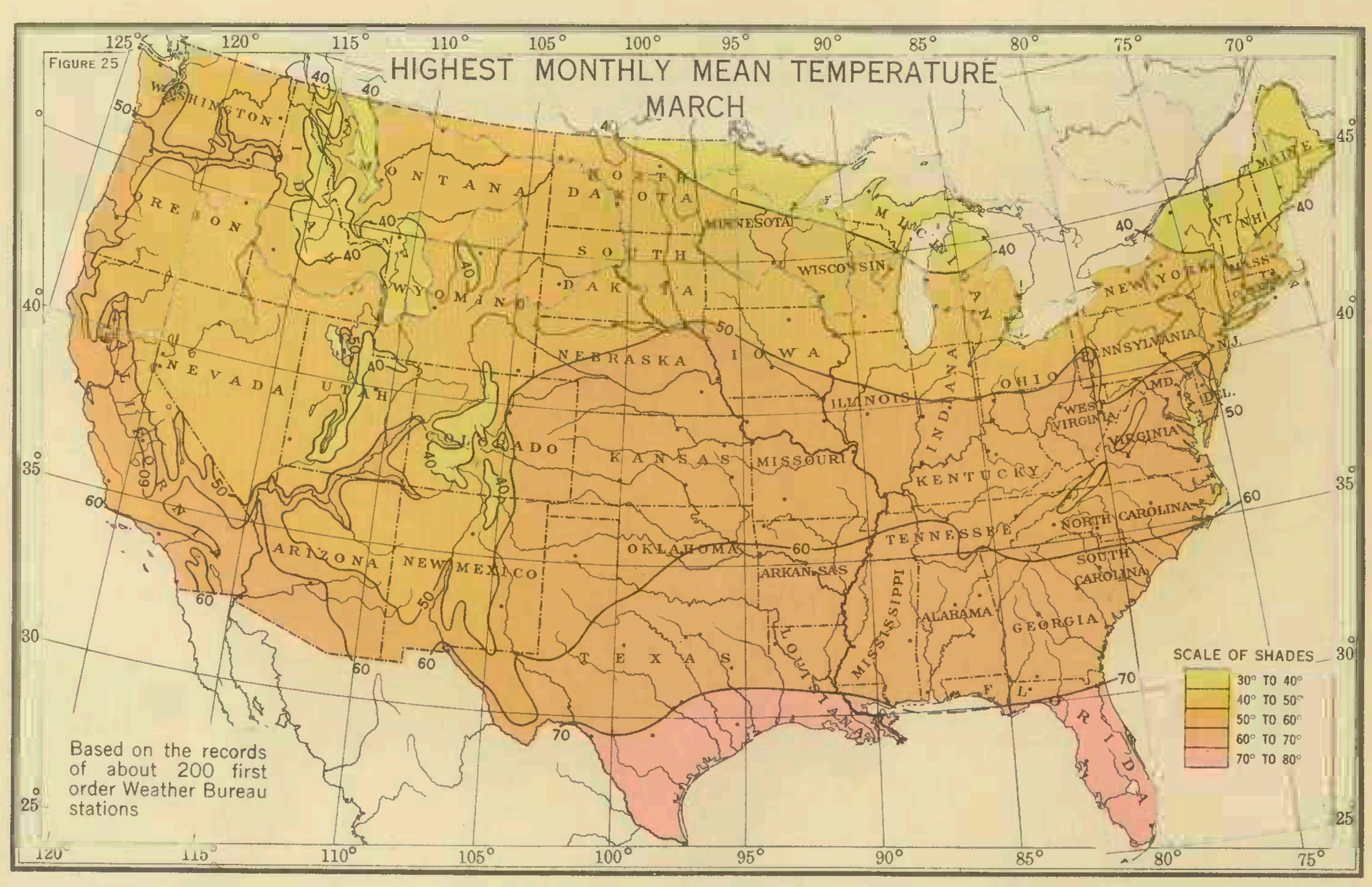
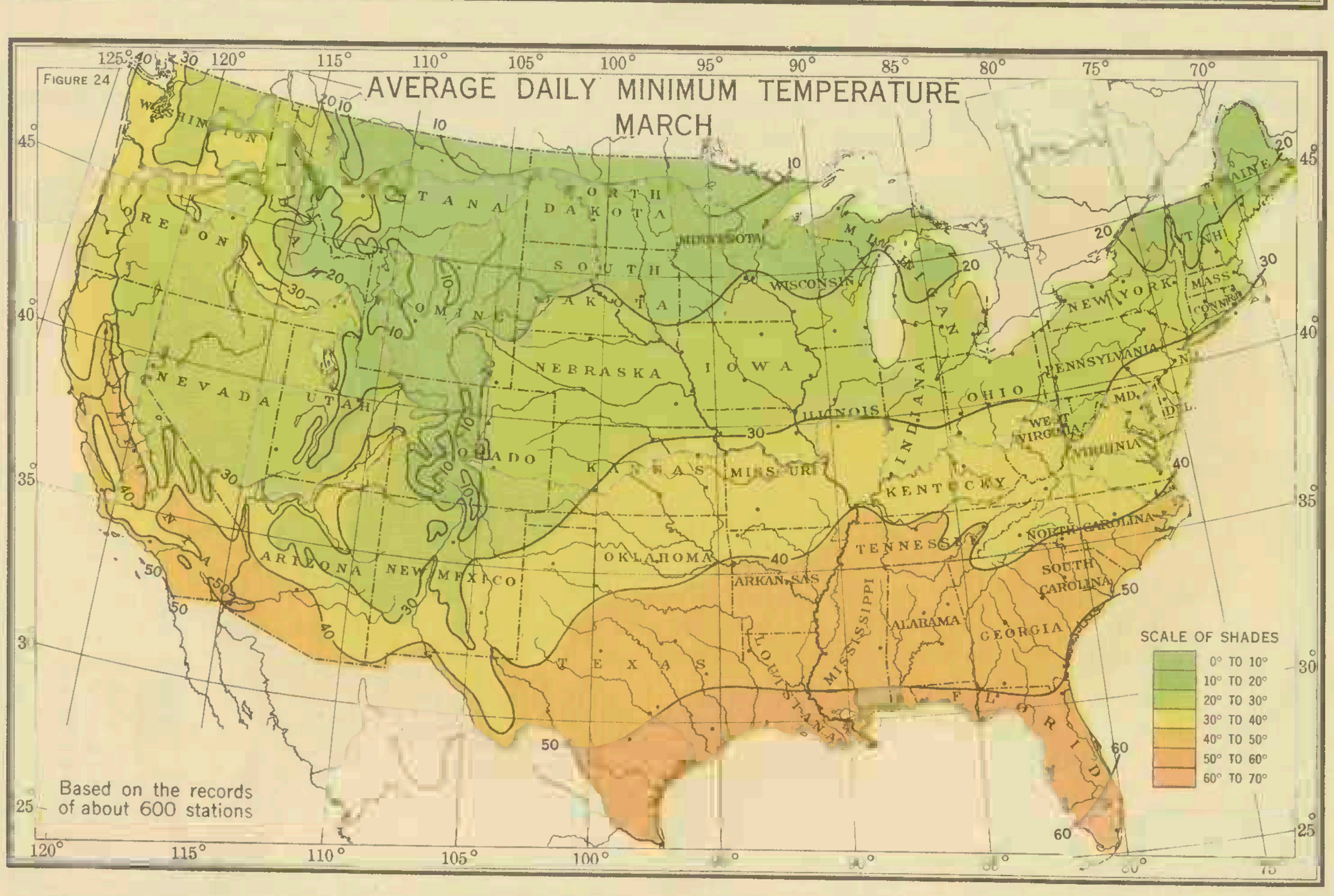
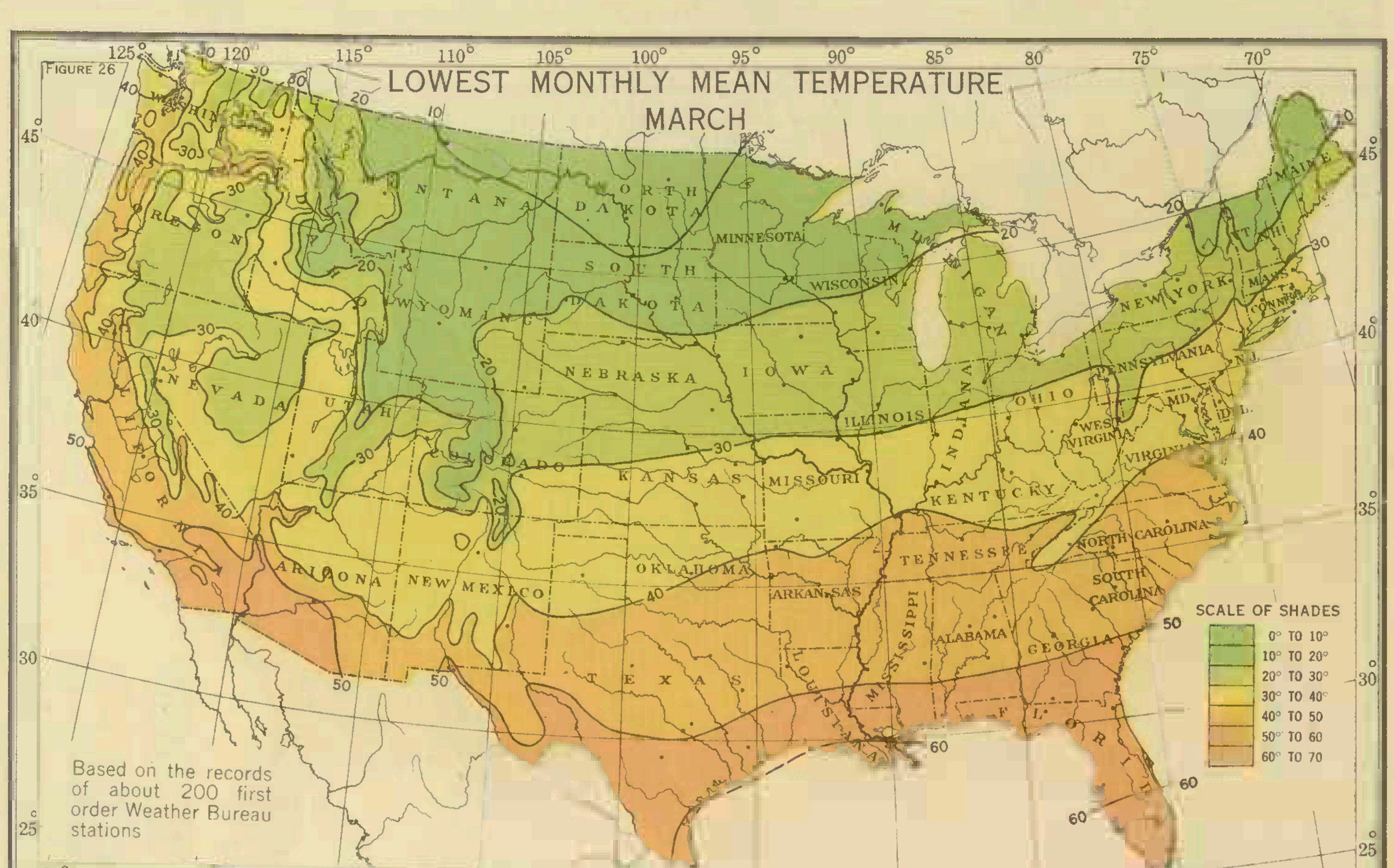


Figure 22.—With the advent of spring there is a rather rapid increase in temperature in most sections of the country. In the northern interior region March is about 15° F. warmer than February, but the increase in temperature from February to March becomes less marked with progress southward, being only about half as great along the Gulf coast as along the northern border of the country. The lowest average temperature for March, about 20°, is found along the northern border in North Dakota and Minnesota, and there is an increase southward to about 60° or 65° along the Gulf coast. In the more northern States extremely cold weather occurs occasionally in this month, from —35° to —40° having been recorded in North Dakota and Montana. But the March cold waves usually lose intensity rapidly in their southward and eastward progress. Temperatures below zero have never been recorded in this month south of the fortieth parallel of latitude, except in the Texas Panhandle, Kansas, and a few localities to the eastward. As a rule freezing weather is not experienced in the Gulf States, except in the extreme northern portions, after March 15









Figures 23 and 24 show for March the average daily maximum and the average daily minimum temperatures. In the northern border States east of the Rocky Mountains the average daily maximum is about 35° F., but this increases southward to about 70° along the Gulf coast and to 80° in portions of the Florida Peninsula and in the lower Rio Grande Valley. In the West the average March maximum varies from somewhat less than 40° in the central and northern Rocky Mountain districts to 80° in the lower Colorado River Valley. The average daily minimum east of the Rockies increases from 10° along the northern border in North Dakota and Minnesota to somewhat more than 50° along the Gulf coast, and to 68° at Key West, Fla. In the West it ranges from about 5° in portions of the Rocky Mountain districts to 50° at San Diego, Calif., and in the lower Colorado River Valley

Figures 25 and 26 show the highest and the lowest mean March temperatures occurring in the 28-year period 1895–1922. The range of variation in the mean temperature for March is much larger than for February, especially in the northern interior States, where the month in one year may be 30° F. warmer than in another year

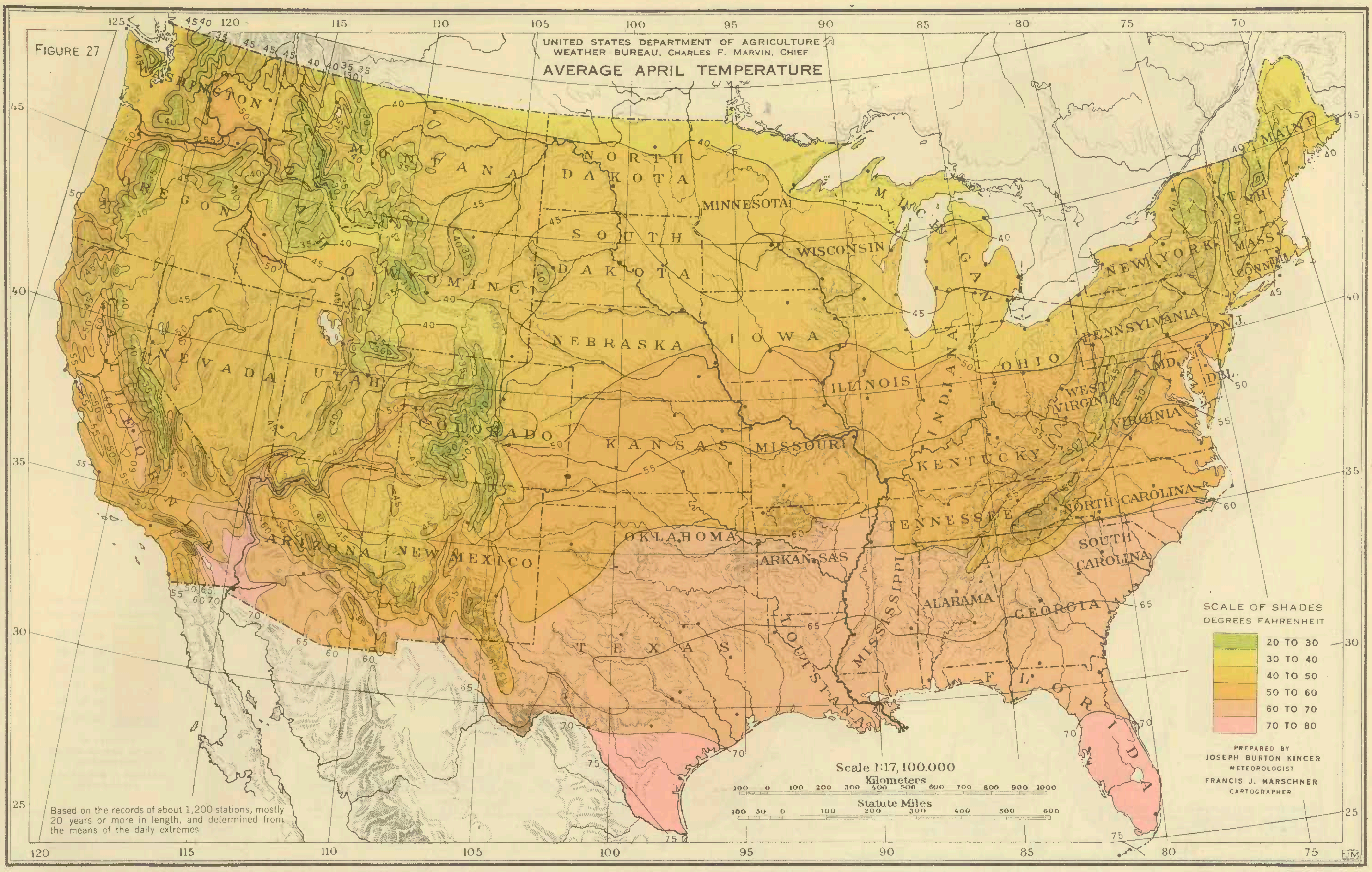
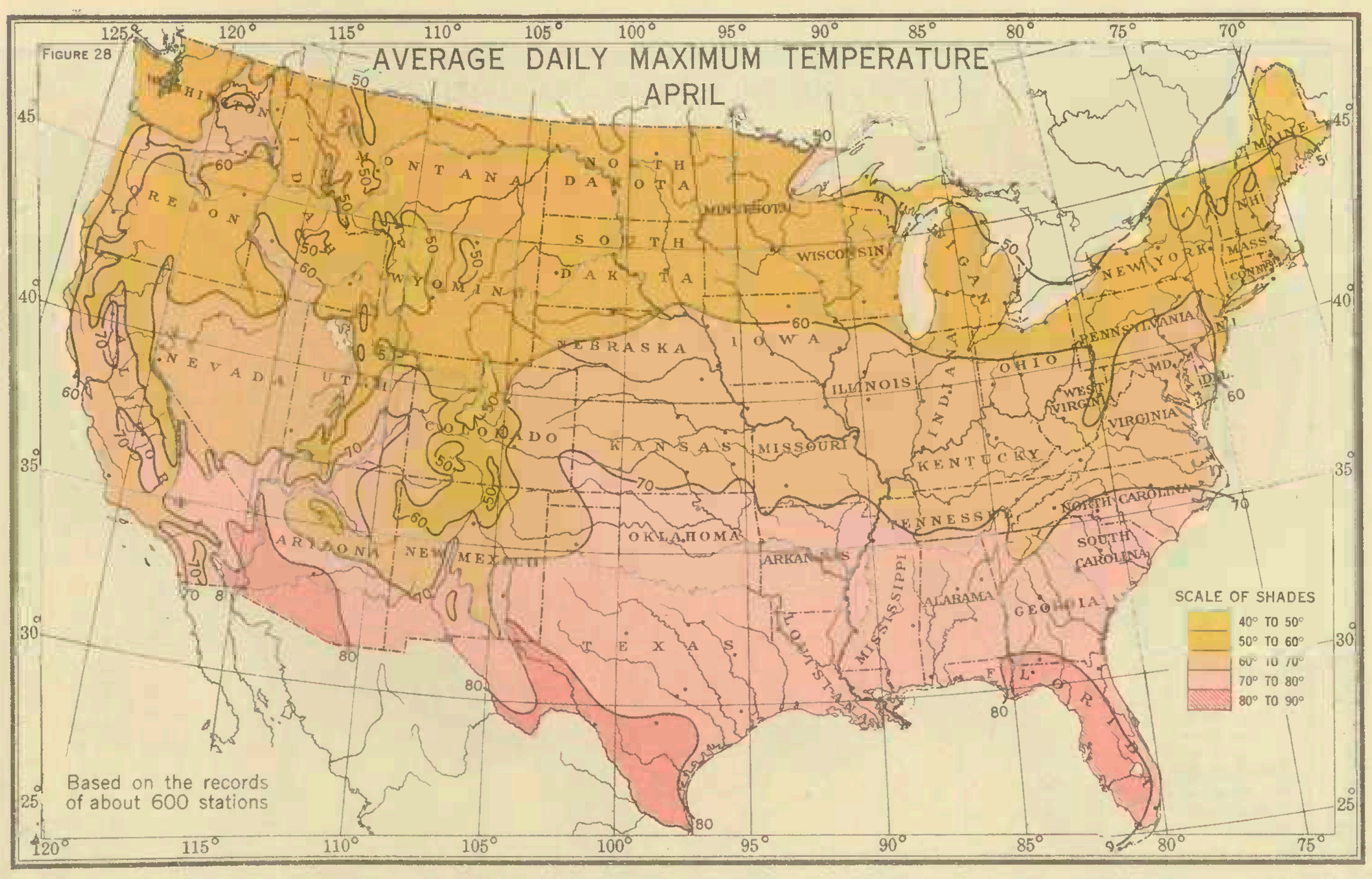
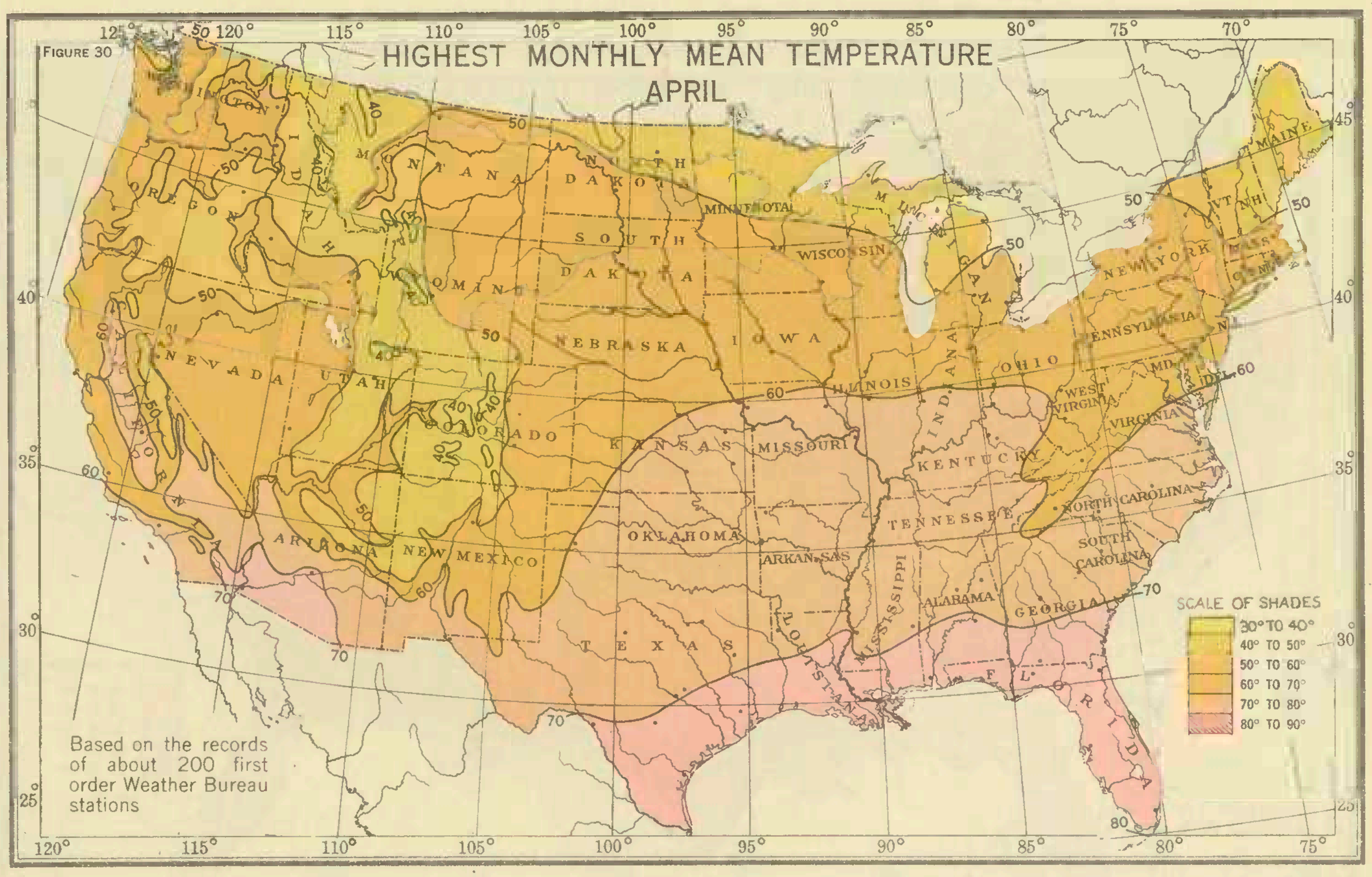
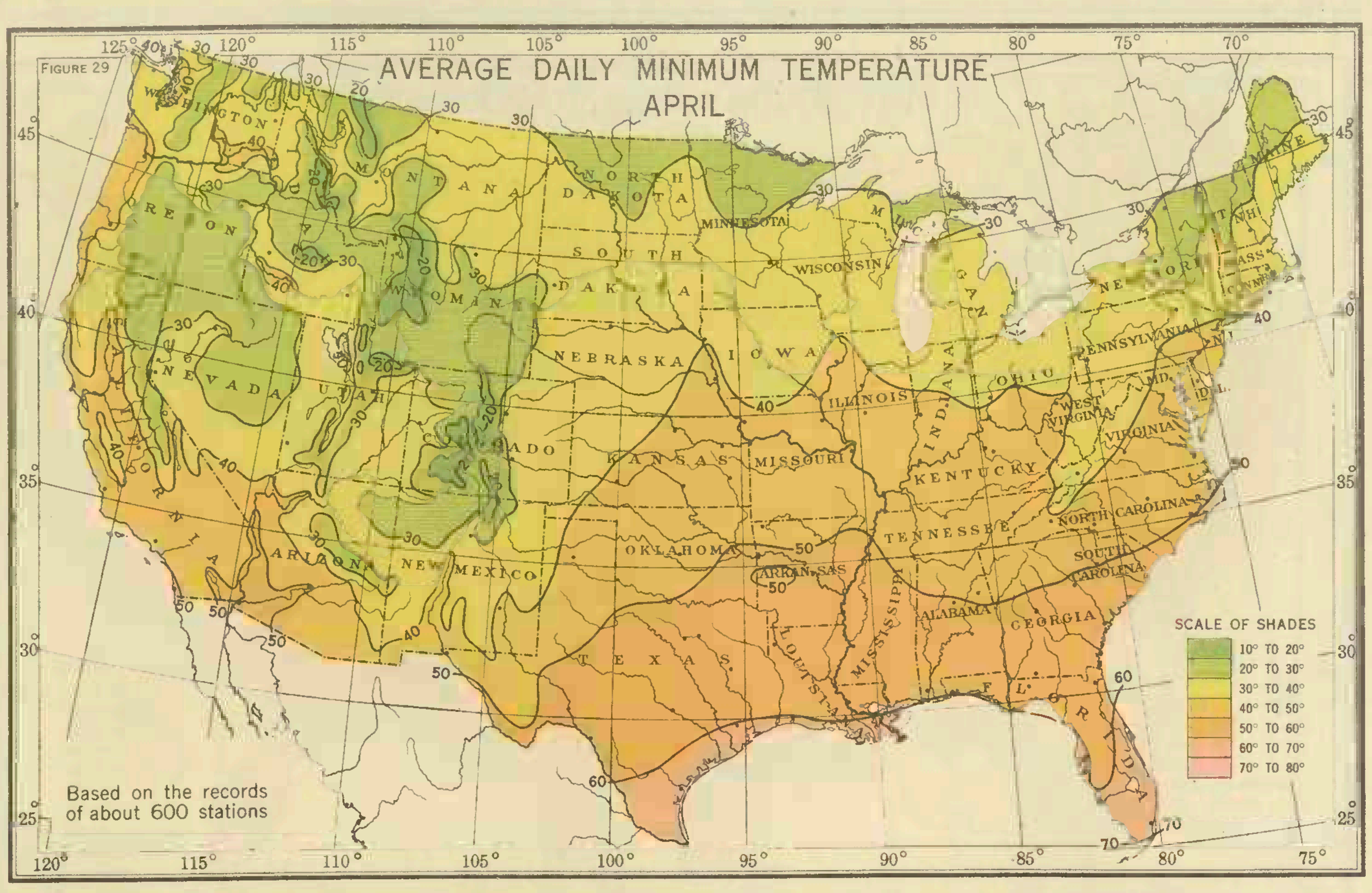
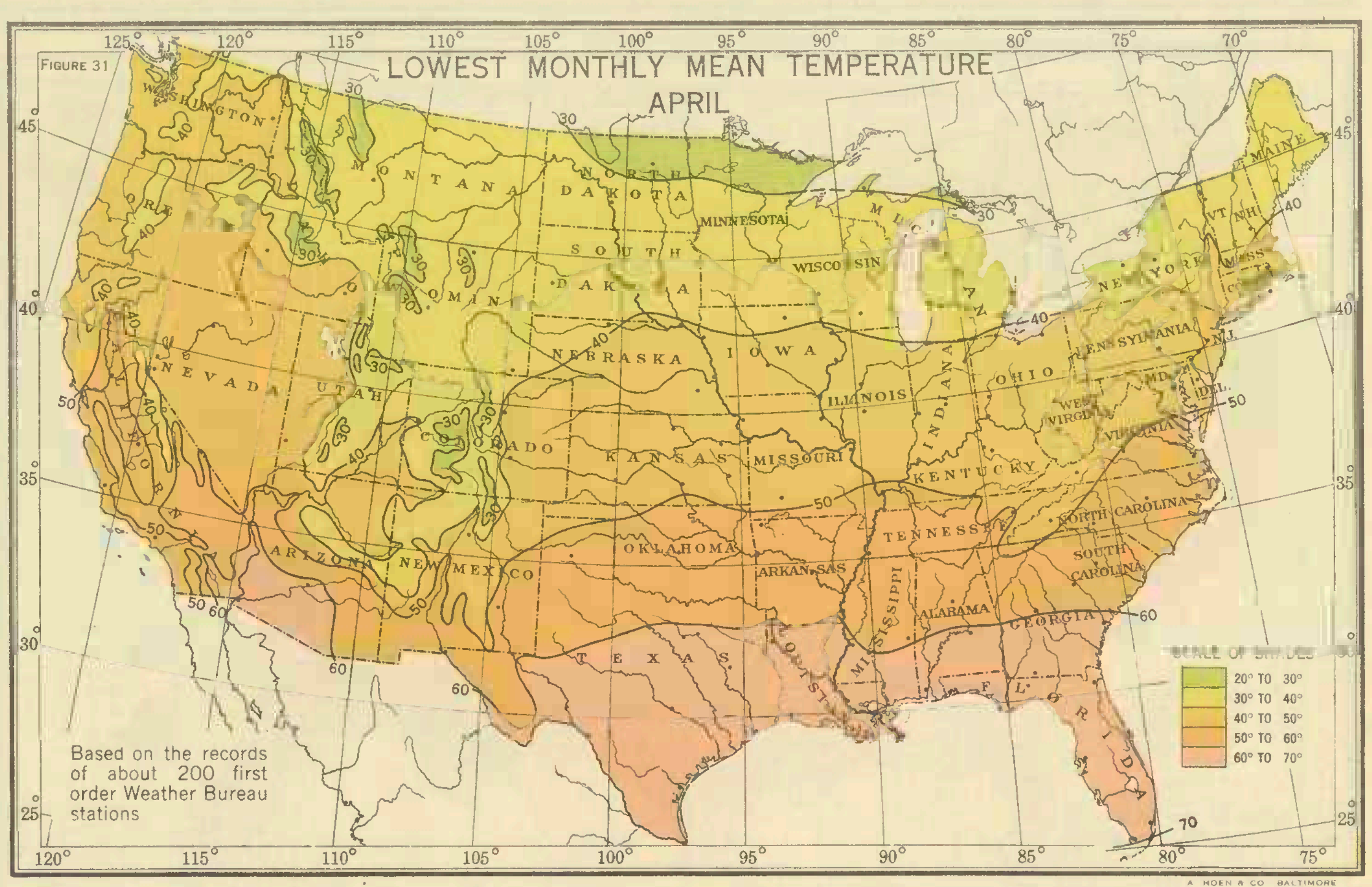


Figure 27.—As spring advances the increase in temperature becomes more pronounced, the average for April in North Dakota and northern Minnesota being nearly 20° F. higher than for March. Southward the increase in temperature becomes progressively less rapid, amounting to about 6° along the Gulf coast. The average temperature for April ranges from about 40° along the Canadian boundary to nearly 70° at the Gulf of Mexico. Along the Pacific coast April is only slightly warmer than March, but in the Interior Plateau and Rocky Mountain districts the increase in temperature during April is rapid. Cold periods occur occasionally during April, the lowest temperature recorded in this month at a regular reporting station of the Weather Bureau located in eastern Montana being —10°. Freezing temperatures have been experienced early in April as far south as Mobile, Ala., but as a rule such temperatures do not occur after the 15th of this month south of a line extending through central Virginia, western North Carolina, and southern Kentucky westward to central Missouri and Kansas









Figures 28 and 29 show for April the average daily maximum and the average daily minimum temperatures. In the principal agricultural districts east of the Rocky Mountains the usual daily temperature range in April varies from about 15° to 27° F., but to the westward, except in the Pacific Coast States, it is considerably larger. (See fig. 82.) East of the Rocky Mountains the average daily maximum for this month ranges from about 45° in northern Maine and the extreme upper Lake region to nearly 80° along the Gulf coast, and the average daily minimum from somewhat less than 30° in the extreme north to about 60° at the Gulf. From the Rocky Mountains westward the average daily maximum varies from somewhat less than 50° at the higher altitudes in the Rocky Mountain region to nearly 90° in southwestern Arizona, and the minimum from about 20° in portions of Colorado and Wyoming to 50° along the coast of southern California and in the lower Colorado River Valley

Figures 30 and 31 show the highest and the lowest mean April temperatures in the 28-year period 1895–1922. The variation in the mean temperature for April in different years is considerably less than for March, but is still large in the northern border States

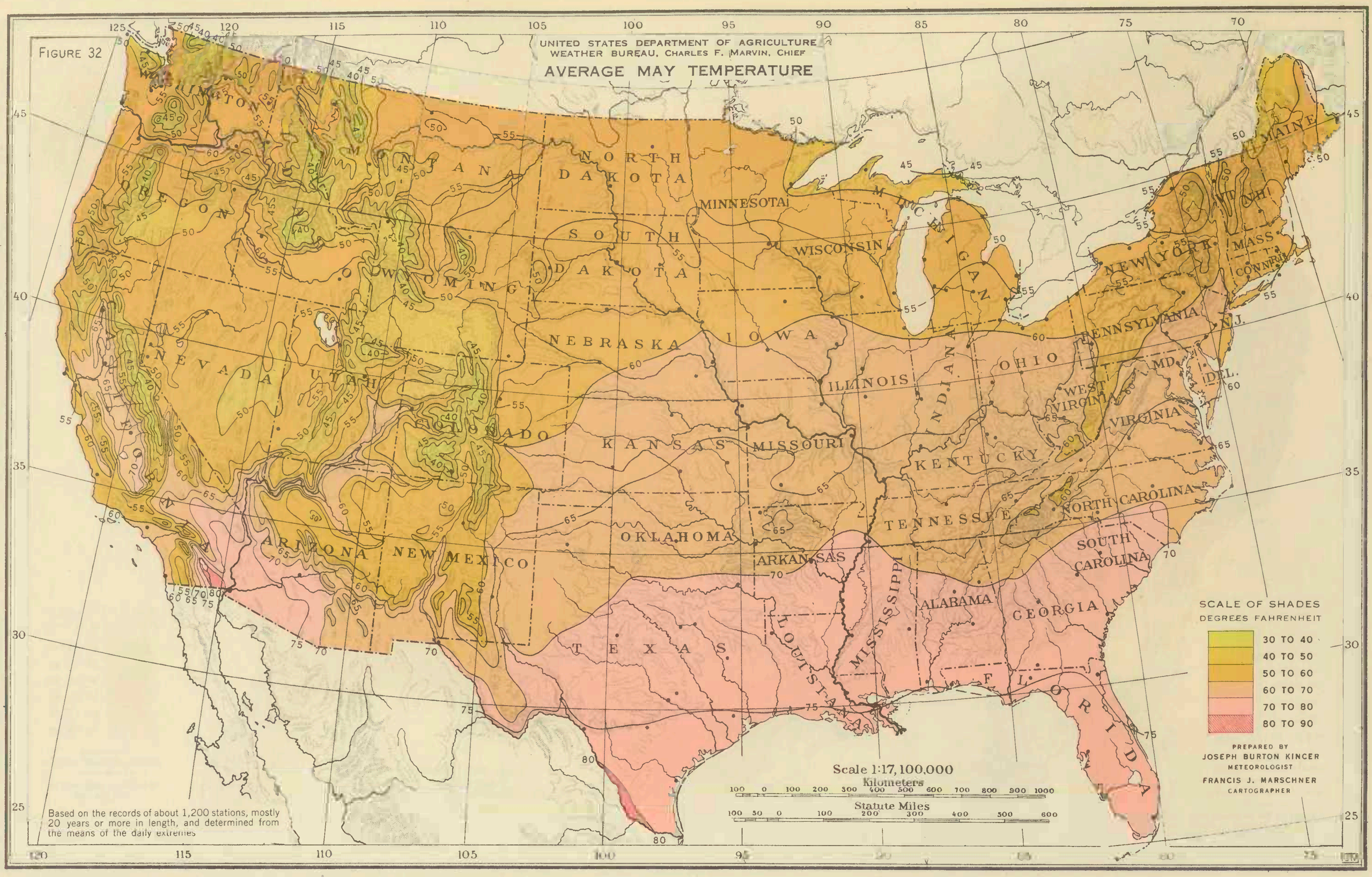
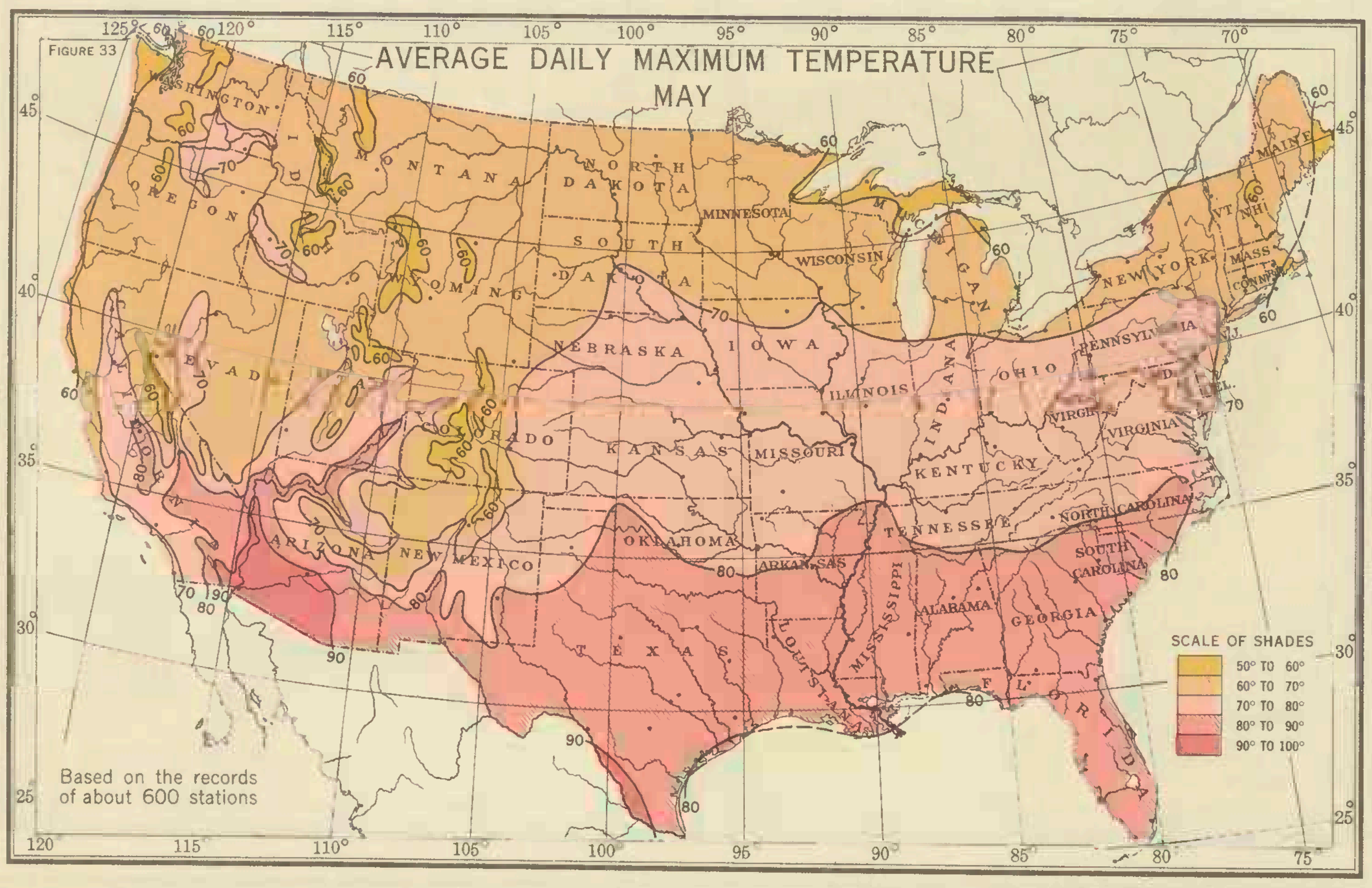
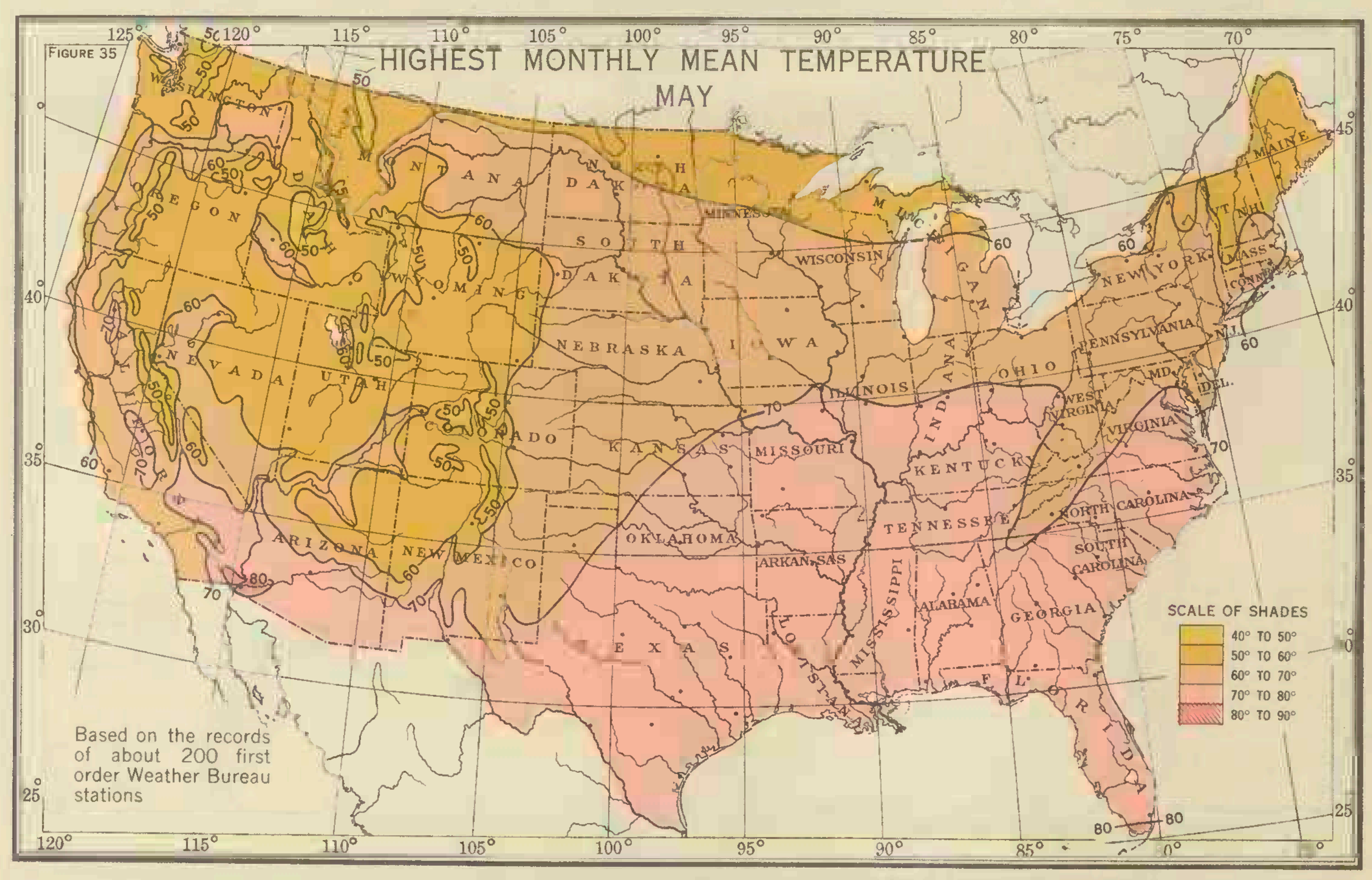
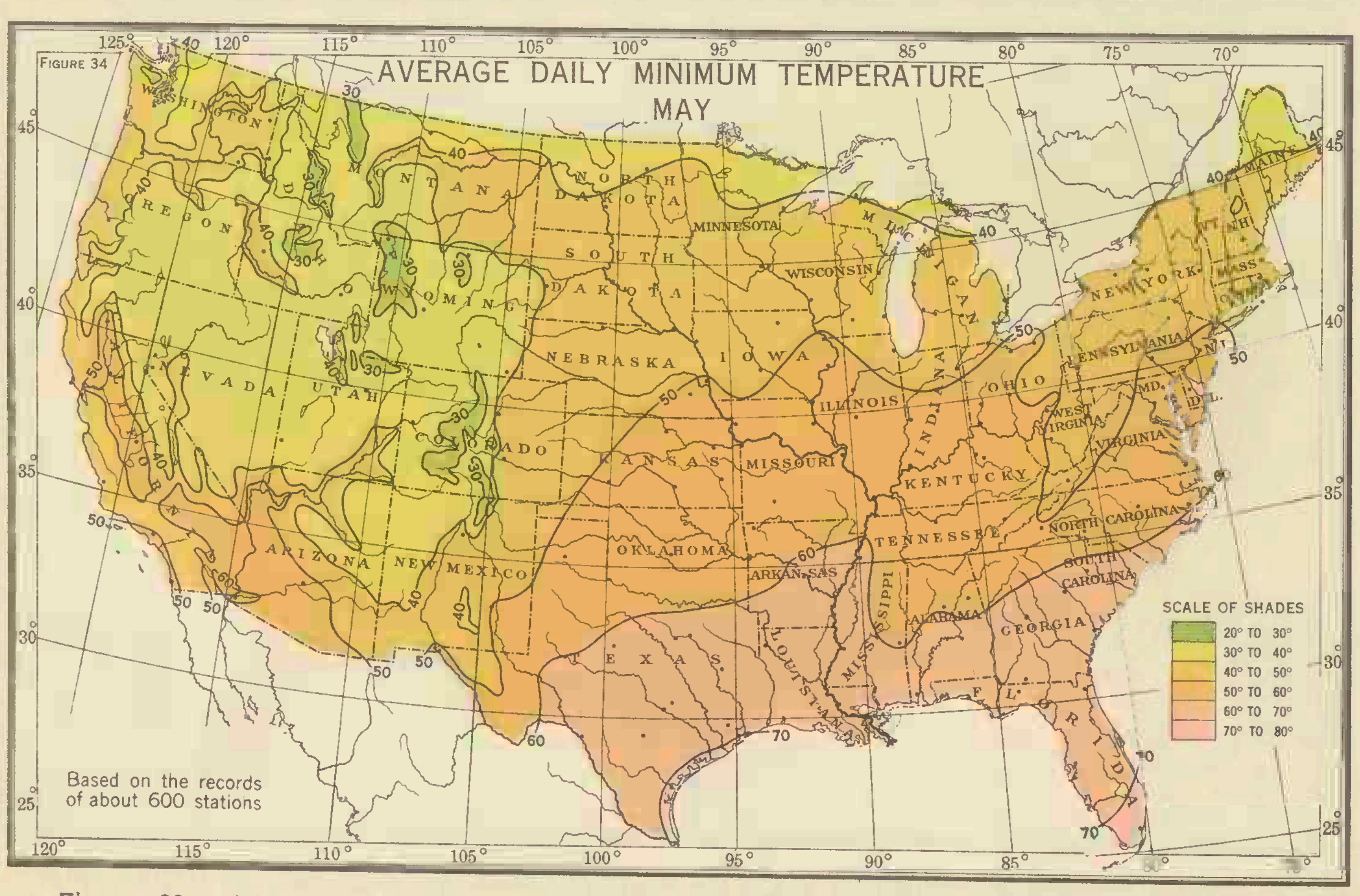
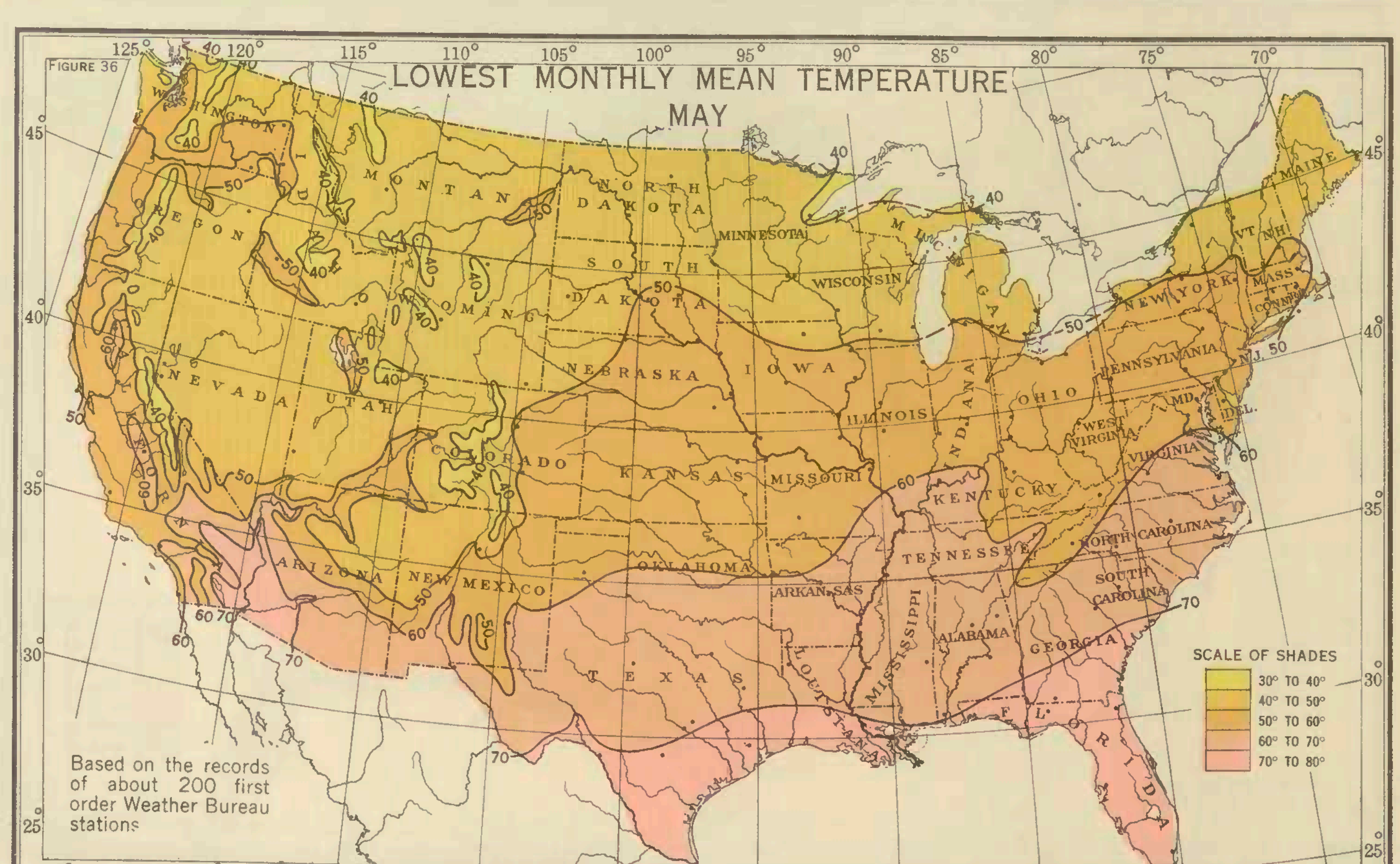


Figure 32.—May throughout most of the United States is usually characterized by the prevalence of mild temperatures. East of the Rocky Mountains the average May temperature ranges from about 50° F. along the northern border of the country to 75° at the Gulf of Mexico, being 5° to 15° higher than for April. Along the immediate Pacific coast it ranges from 50° at the north to 60° at the south. In the lower Rio Grande and Colorado River Valleys the average May temperature is slightly over 80°. The lowest temperature of record in May at a regular reporting station is 6° in northern North Dakota. Freezing temperature has occurred in this month as far south as northern Texas, but east of the Mississippi River freezing weather has never been known south of the Ohio River and southern Pennsylvania, except in elevated districts. As a rule freezing temperatures do not occur after May 10 south of South Dakota, the central portions of Iowa and Wisconsin, and the lower Lakes. High temperatures sometimes occur in May, especially in the Great Valley of California and in the lower Colorado River Valley, 110° having been recorded at Red Bluff and Fresno, Calif., and 120° at Yuma, Ariz.









Figures 33 and 34 show for May the average daily maximum and the average daily minimum temperatures. East of the Rocky Mountains the average daily maximum increases from about 60° F. in the upper Lake region and along the eastern Maine coast to 85° in the southern section of the Cotton Belt, but along the immediate Gulf coast it is only about 80°. In the West the average daily maximum temperature varies from about 60° at the higher altitudes in the Rocky Mountain States and also along the north Pacific coast to 95° in the lower Colorado River Valley. The average daily minimum for May east of the Rocky Mountains ranges from about 40° along the northern border of the country to about 70° along the immediate Gulf coast, and in the West from less than 30° in the central Rocky Mountain districts to 60° in the lower Colorado River Valley

Figures 35 and 36 show the highest and the lowest mean May temperatures in the 28-year period 1895–1922. The lowest mean temperature for May experienced during this 28-year period ranges from about 40° F. in the upper Lake region and in some of the Rocky Mountain districts to 73° along the Gulf coast

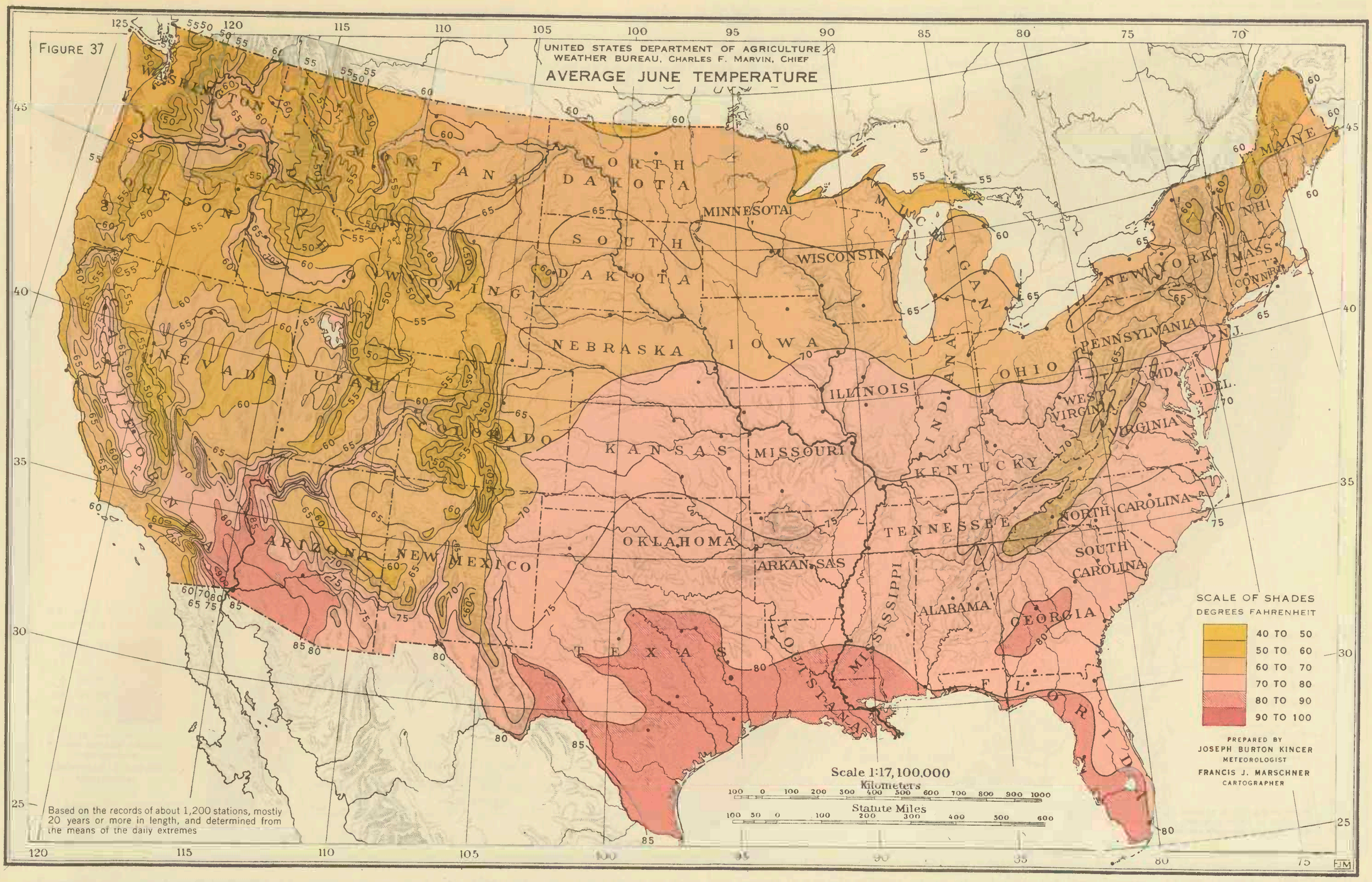
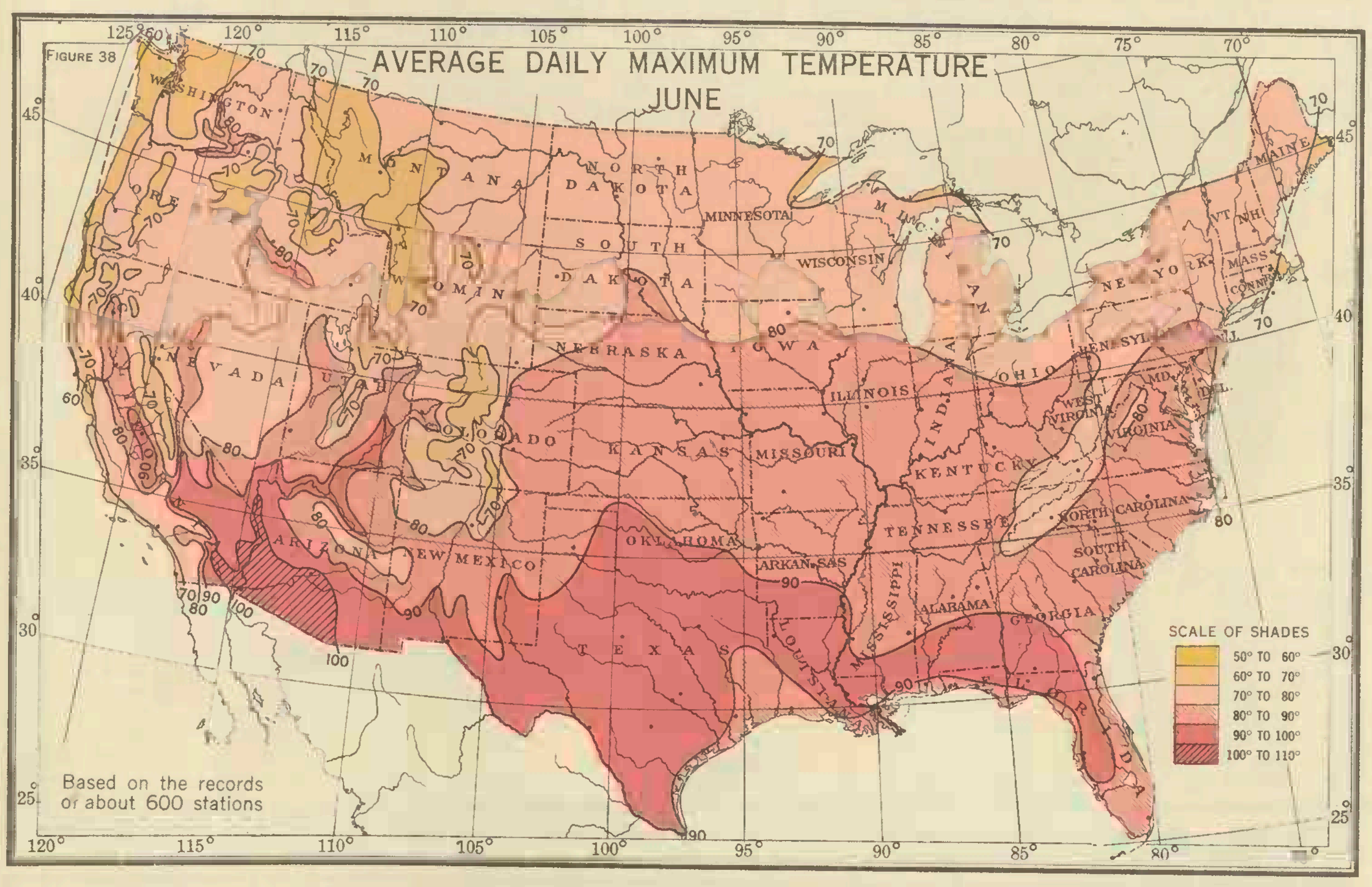
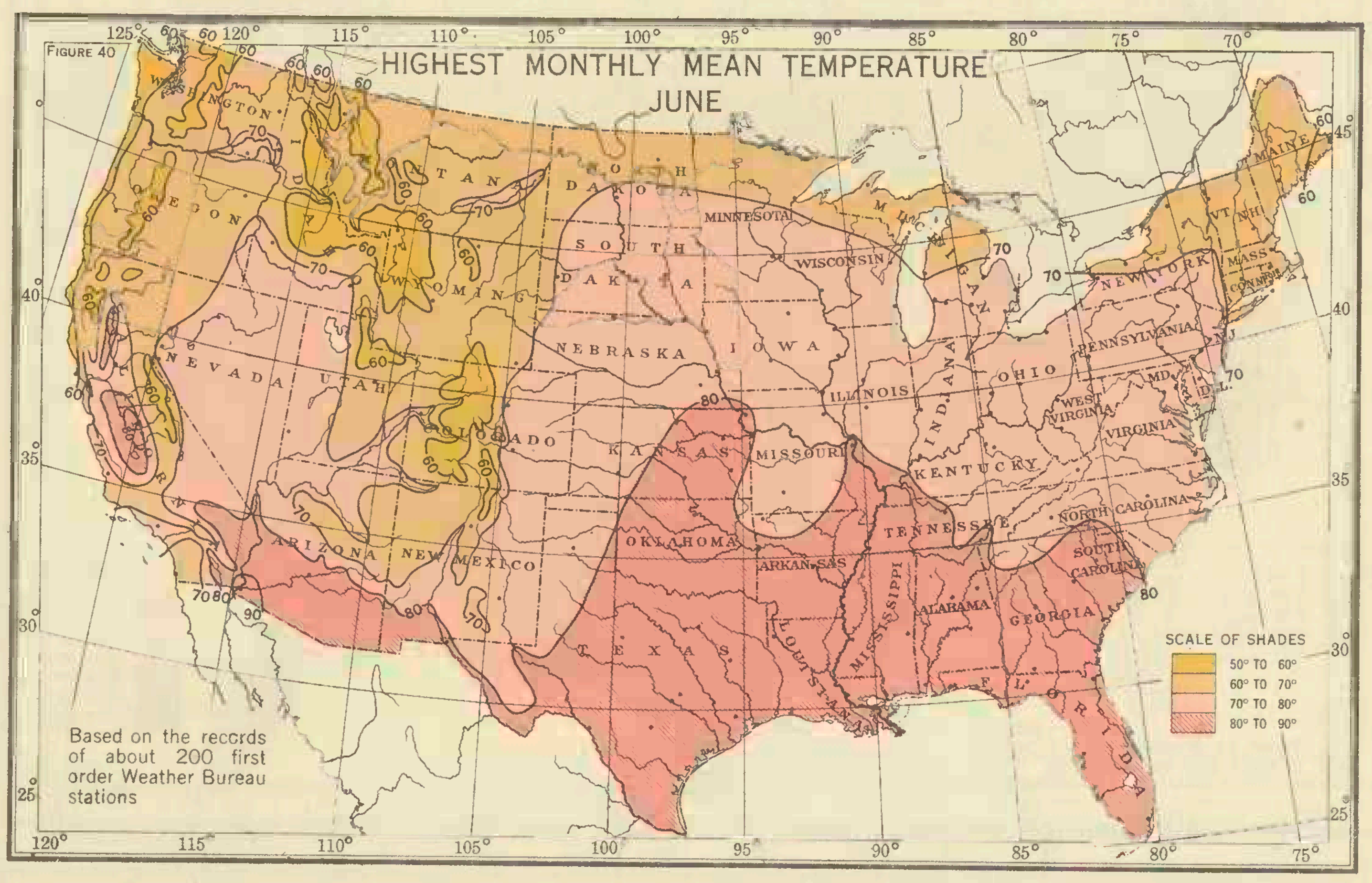
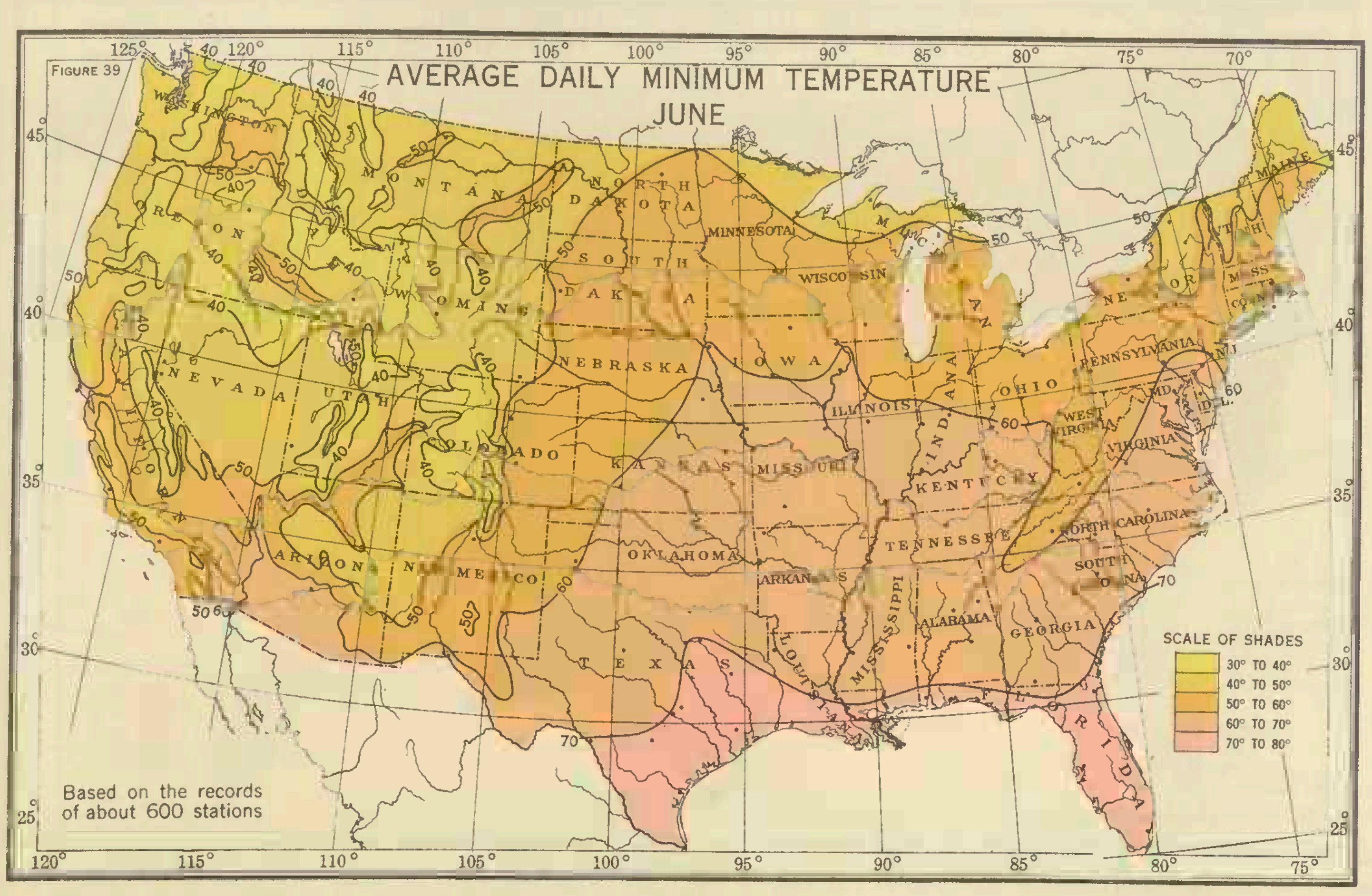
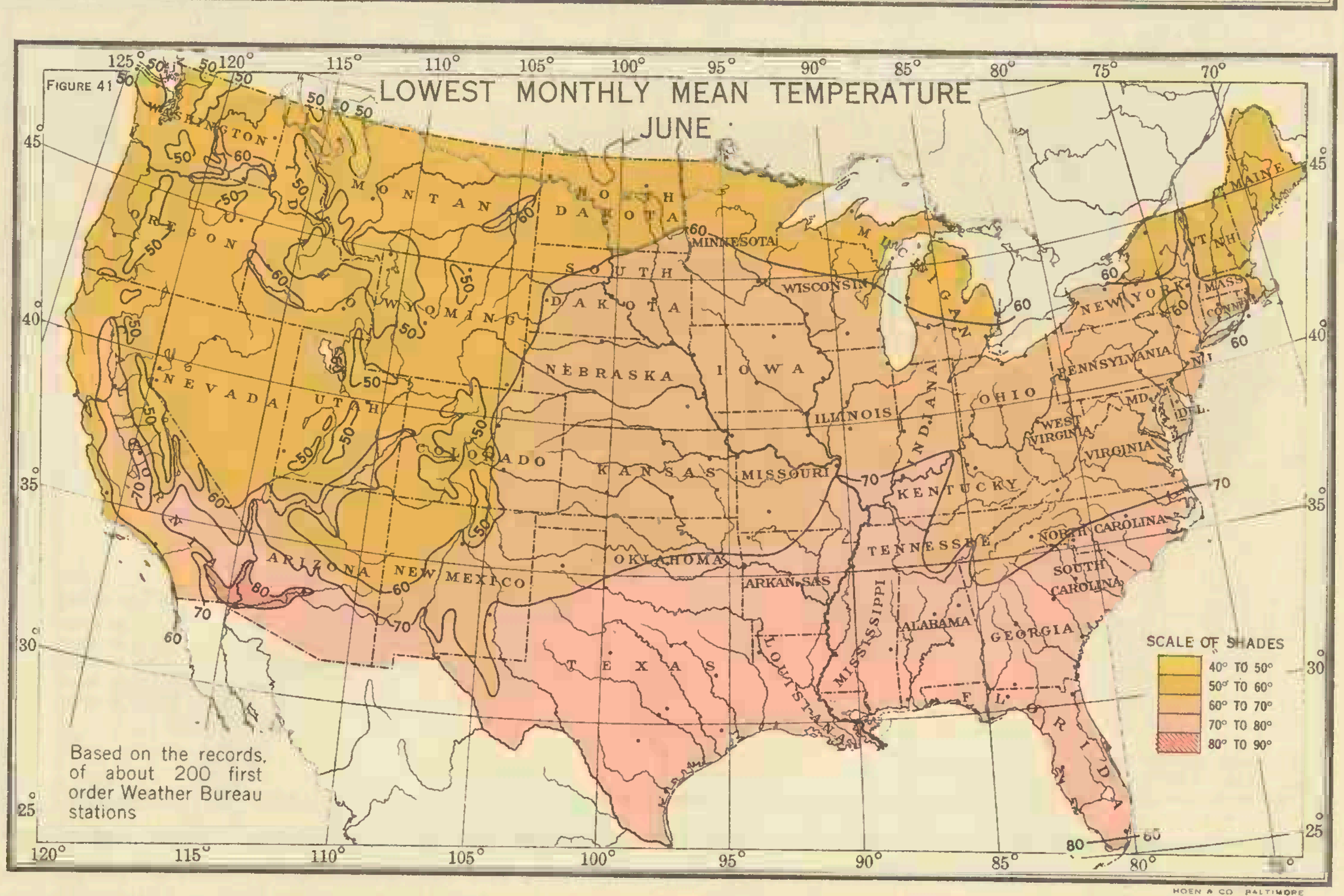


Figure 37.—In June the average temperature along the Canadian border east of the Rocky Mountains is about 60° F., or approximately 10° higher than in May. To the southward there is a rather pronounced increase to 70° in central Iowa and Ohio, and thence a less rapid rise to about 80° in the Gulf coast section. At the lower elevations in the West the average June temperature is mostly between 60° and 70°, but in some of the southern districts it is much higher, reaching 90° in the lower Colorado River Valley. Along the immediate Pacific coast it ranges from 55° at the north to 65° at the south. High temperatures occur occasionally during June, the highest of record at a regular reporting station of the Weather Bureau being 117° at Yuma, Ariz. Temperatures of 106° to 110° have been experienced in June in the Great Plains States, and 100° or higher has occurred quite generally throughout the country, except in the Northeastern States, in the Great Lakes region, in the higher altitudes of the Rocky and Appalachian Mountain districts, and along the central and north Pacific coast









Figures 38 and 39 show for June the average daily maximum and the average daily minimum temperatures. East of the Rocky Mountains the average daily maximum for June ranges from about 70° F., in the upper Lake region and on the north Atlantic coast to about 90° in the southern portion of the Cotton Belt, increasing to nearly 100° in the lower Rio Grande Valley. In the West the average daily maximum ranges from 60° along the north Pacific coast and less than 70° in the central and northern Rocky Mountain districts to about 105° in the lower Colorado River Valley. The average daily minimum temperature ranges from less than 40° in the central and northern Rocky Mountain districts and 50° along the northern border of the country to about 75° along the immediate Gulf coast

Figures 40 and 41 show the highest and lowest mean June temperatures in the 28-year period 1895–1922. Variation in the mean temperature for June during this period is not pronounced in any section of the country. In the principal agricultural districts it is generally about 10° F. and along the Pacific coast is only 5°

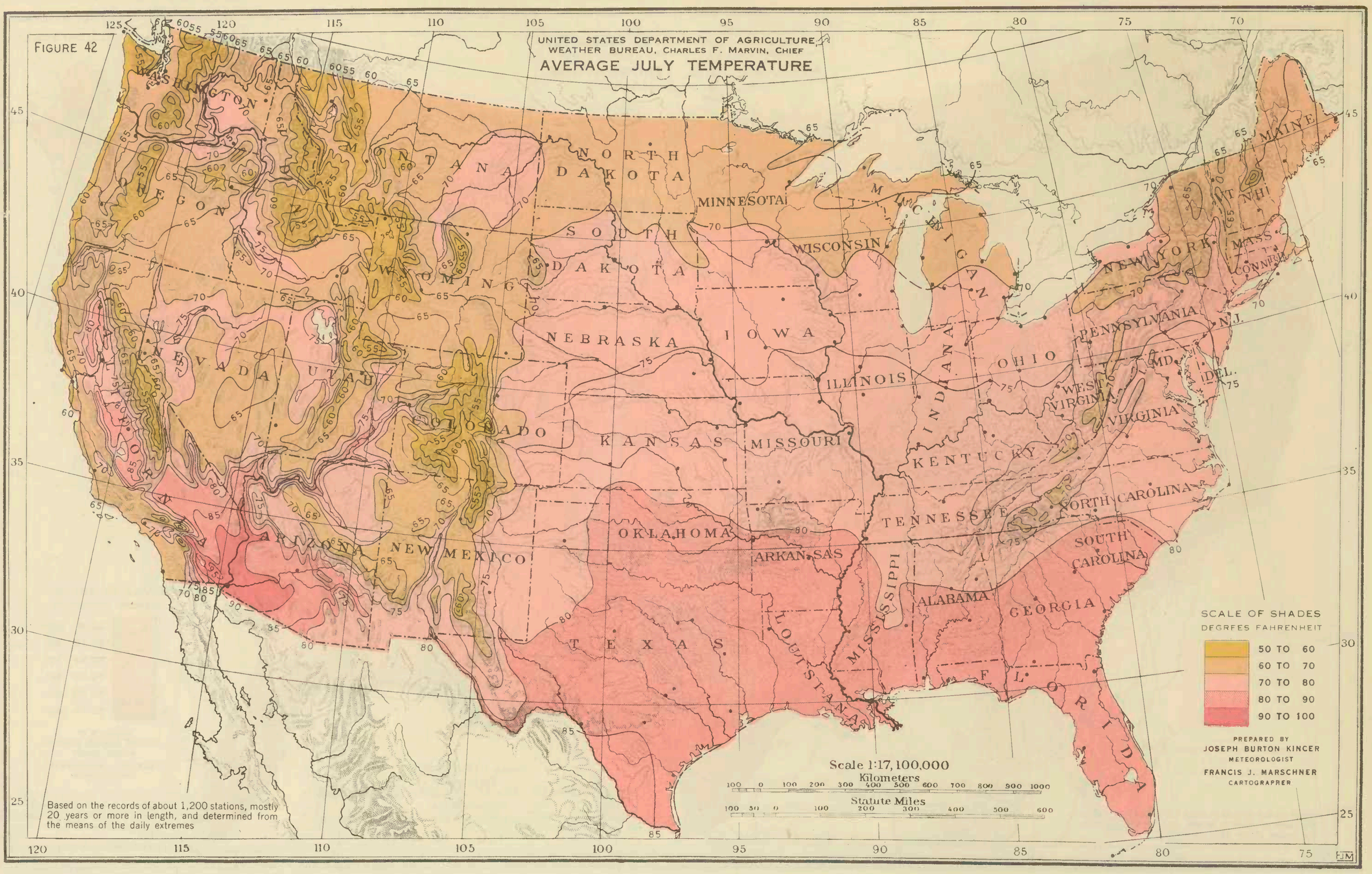
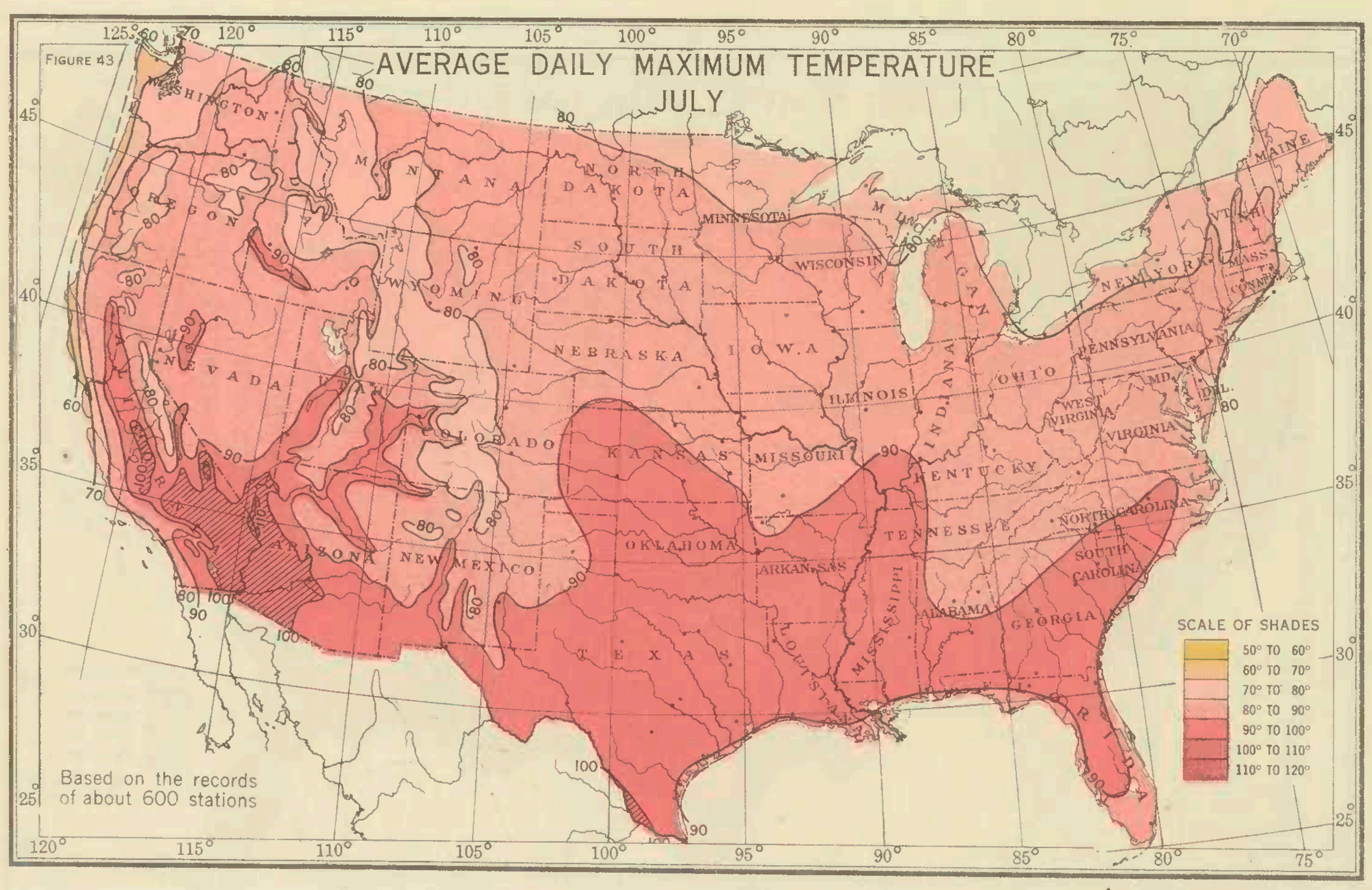
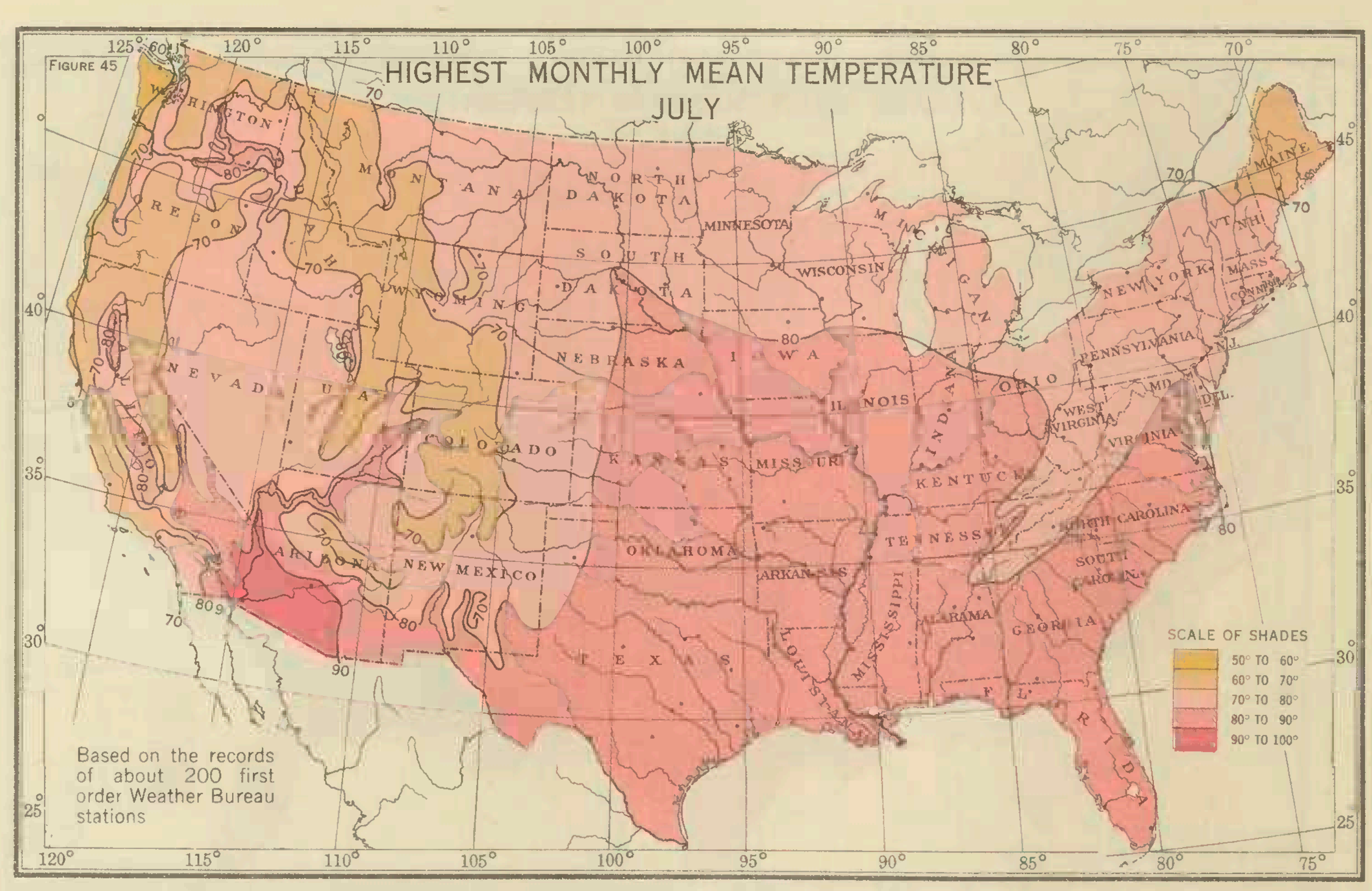
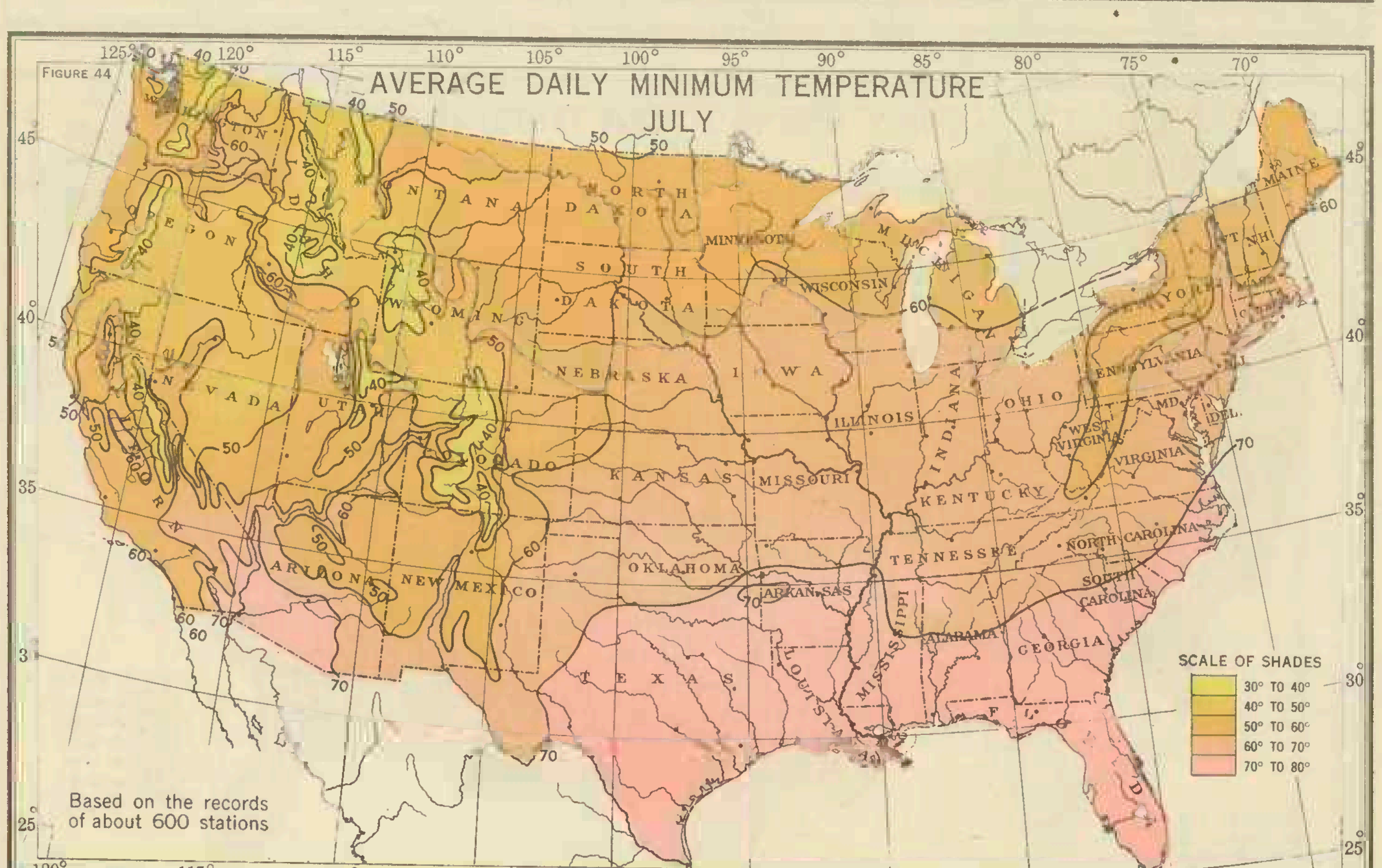
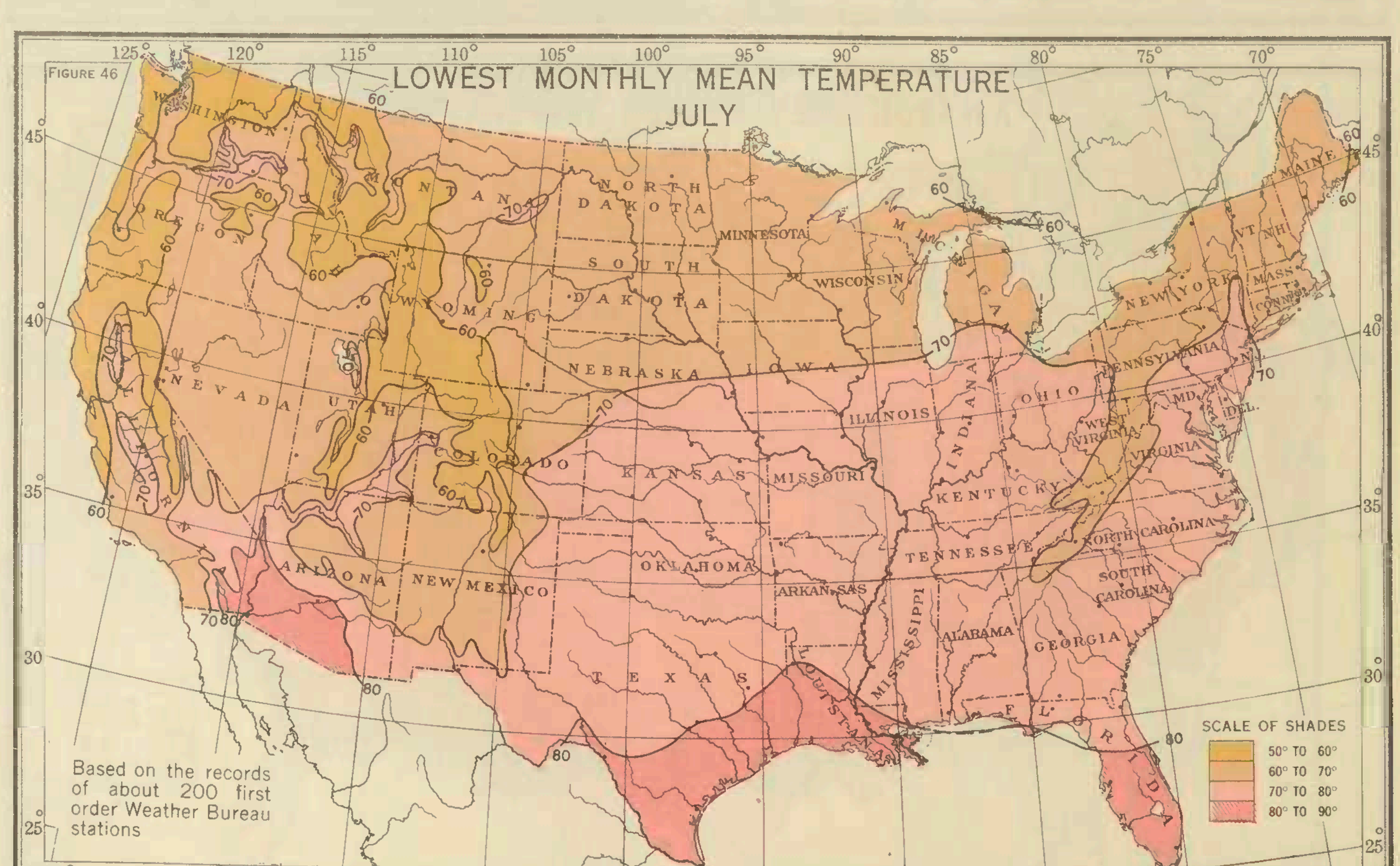


Figure 42.—July is usually the warmest month of the year, except along the Pacific coast, where the marine type of climate prevails. East of the Rocky Mountains the average July temperature ranges from between 55° and 70° F. in the northern border States to about 82° on the Gulf coast. Along the Pacific coast it increases from about 55° at the north to 67° at the south. The highest July temperature usually occurs in southwestern Arizona and southeastern California, where the average for the month varies from 90° to 98°. In July periods of hot weather are comparatively frequent in the interior sections of the country. In some of the important agricultural districts, particularly in the Middle West, the heated periods are occasionally accompanied by hot winds which are injurious to vegetation. July temperatures of from 105° to 110° have been experienced in nearly all localities between the Rocky Mountains and the Mississippi River and at many points to the eastward. However, along the central and north Pacific coast in the higher altitudes of the Rocky and Appalachian Mountains and likewise at points along the north Atlantic coast and in the Florida Peninsula the highest temperatures ever recorded are less than 100°









Figures 43 and 44 show for July the average daily maximum and the average daily minimum temperatures. The average daily maximum east of the Rocky Mountains ranges from between 70° and 80° F. along the Canadian Border to about 100° in the lower Rio Grande Valley, and in the far West from about 60° along the north Pacific coast to nearly 110° in the lower Colorado River Valley. The average daily minimum ranges from less than 40° in the higher Rocky Mountain districts and about 50° in northern North Dakota to 75° along the Gulf coast and in the lower Colorado River Valley. The average daily range in temperature in July in the Eastern States is mostly from 20° to 25°, except along the coasts of the Great Lakes and Atlantic Ocean, and in the Western States is from 25° to 45°, except along the immediate Pacific coast. (See fig. 83.) This is 5° to 10° greater than in January

Figures 45 and 46 show the highest and the lowest mean July temperatures in the 28-year period 1895–1922. Variations in the mean July temperature from year to year are, as a rule, not pronounced, the extreme range being in most districts from 5° to 7° F., as compared with 10° to 20° for January

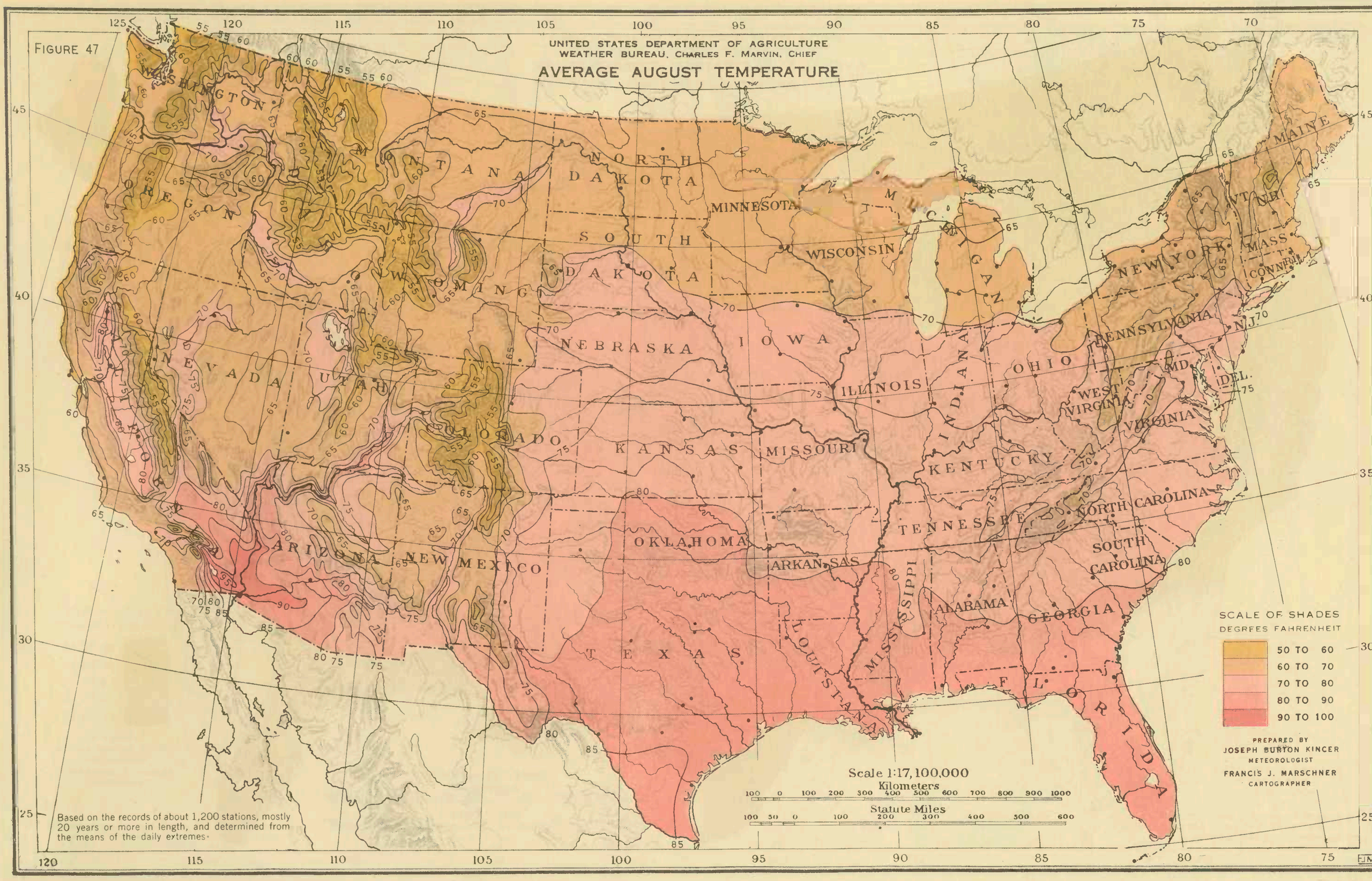
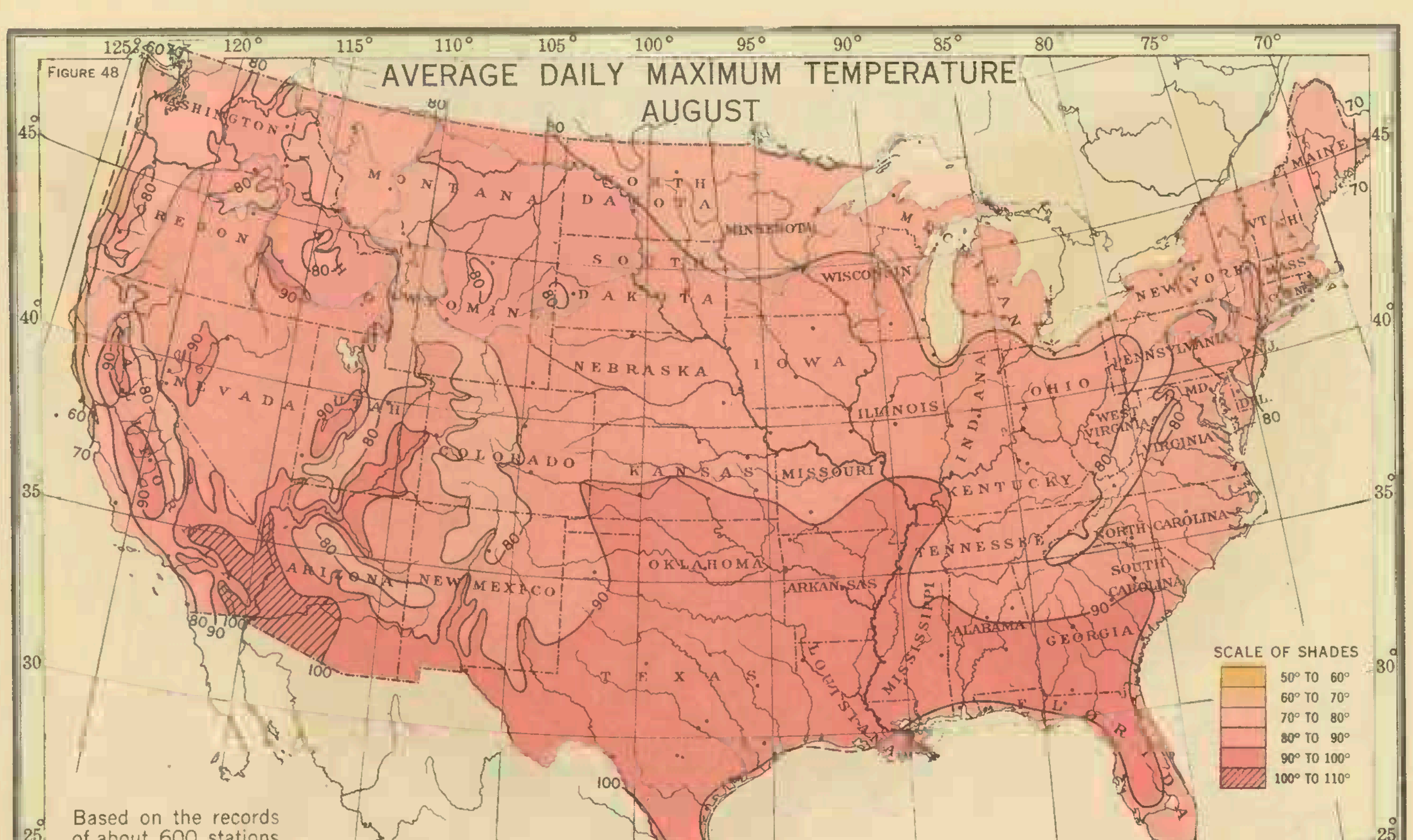
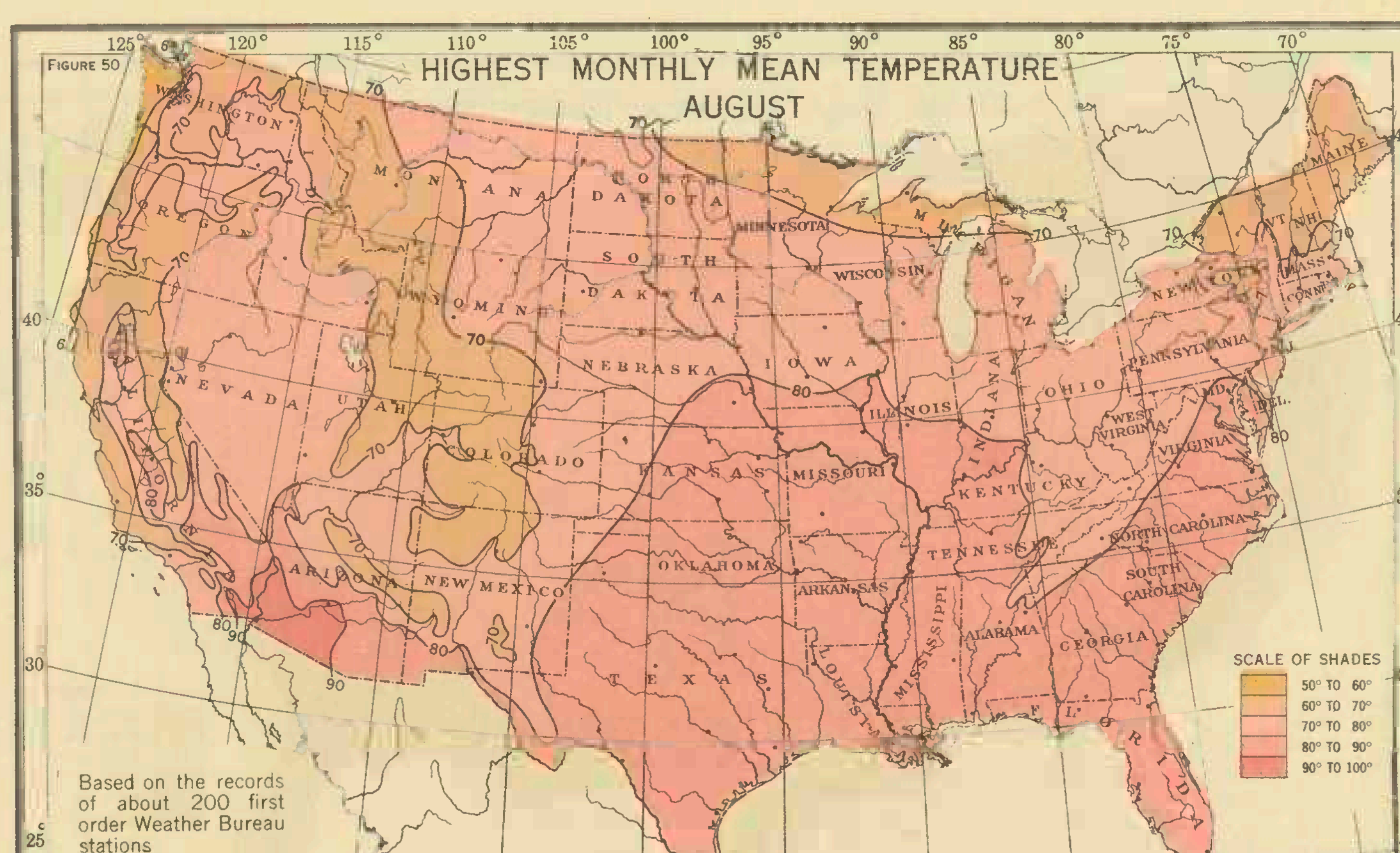
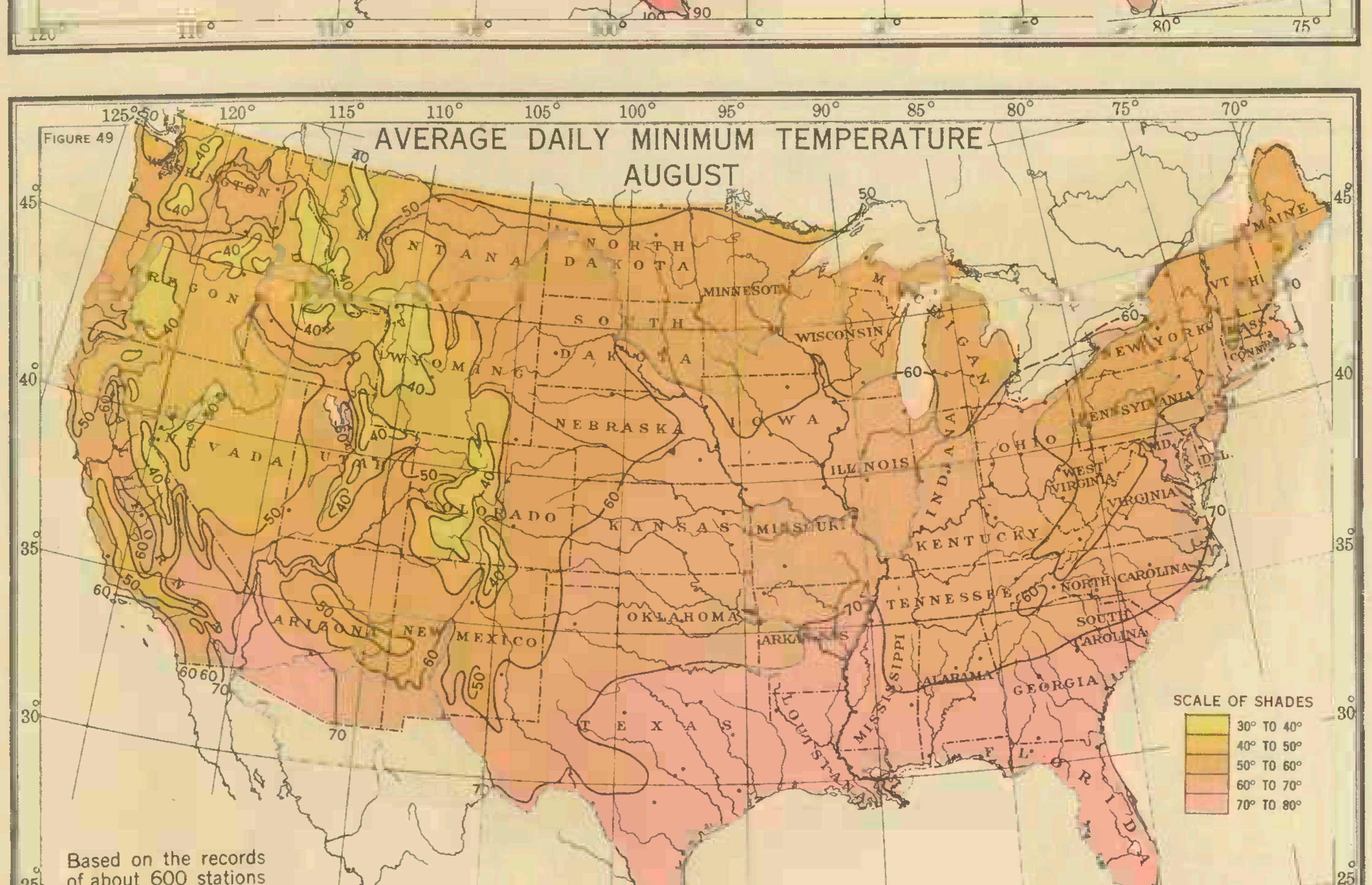
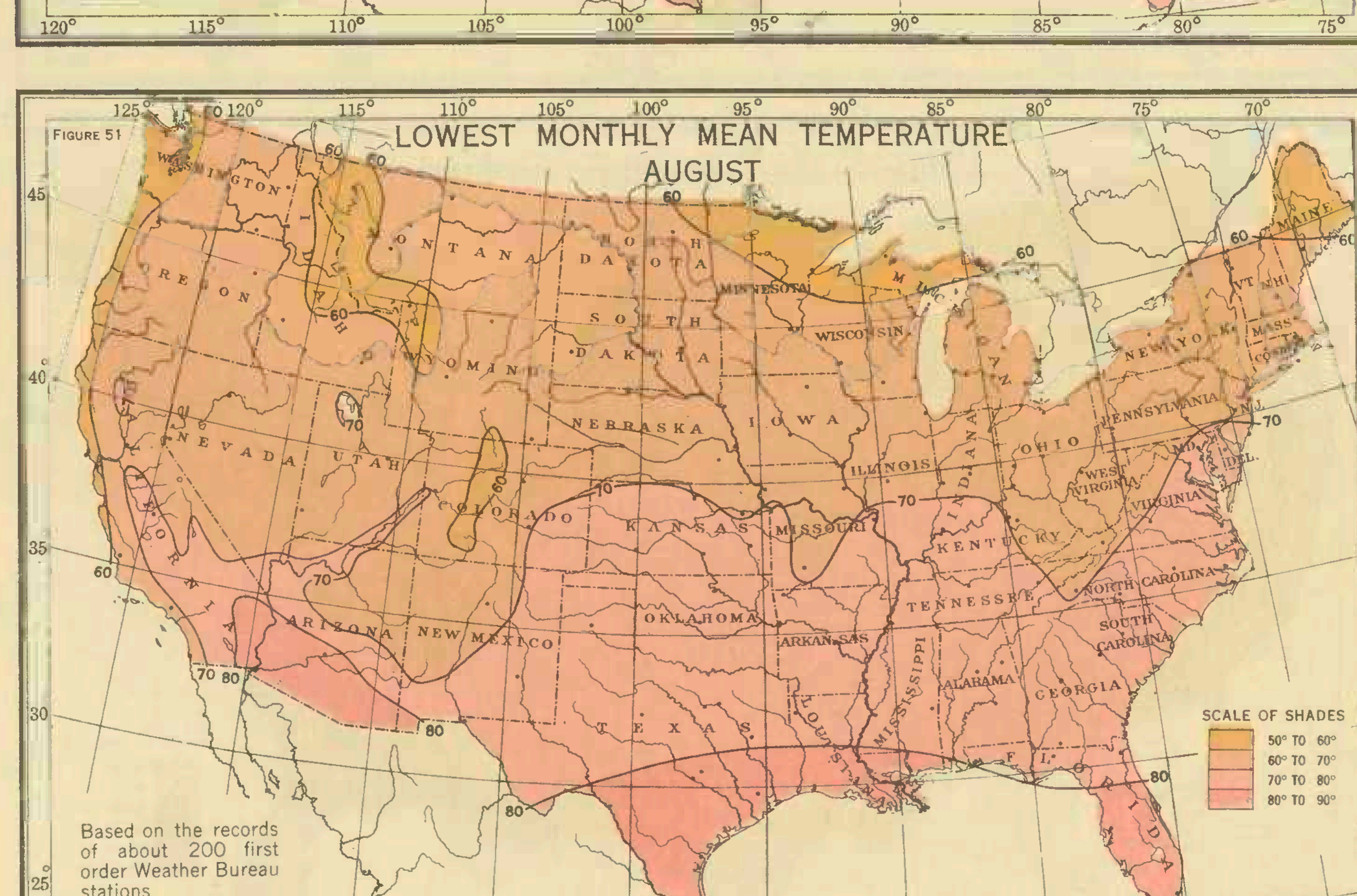


Figure 47.—During August temperature conditions do not, as a rule, differ materially from those in July, but August is usually slightly cooler, except along the Pacific coast. At some points on the Pacific coast September is even warmer than August. East of the Rocky Mountains the coolest August weather usually occurs in northern Michigan and in the highlands of New York and New England, where the average temperature for the month ranges from 60° to 65° F. The temperature gradient from north to south is much smaller in summer than in winter. In July and August the difference between the average temperature along the Canadian boundary and that on the Gulf coast is about 15°, but in midwinter it is about 50°. Along the immediate Pacific coast the characteristic cool summer weather usually continues during August, but in the Great Valley of California and in southwestern Arizona hot weather often prevails, the average temperature in the lower Colorado River Valley reaching 95°. Temperatures as high as 116° have been experienced in August in the lower Colorado River Valley, 113° at points in the Great Valley of California and eastern Washington, 112° in northeastern Texas, and 110° locally in the northern Great Plains region









Figures 48 and 49 show for August the average daily maximum and average daily minimum temperatures. Along the immediate Pacific coast the daily maximum temperature during this month is low, ranging from 60° F. at the north to 74° at the south. In the southern portion of the Great Valley of California the average daily maximum temperature is near 100°, and in the lower Colorado River Valley it reaches 108°. East of the Rocky Mountains the average daily maximum temperature ranges from about 72° in northern Michigan and 70° on the eastern Maine coast to 100° in the lower Rio Grande Valley. The average daily minimum for August ranges from about 35° in the higher altitudes of the middle and northern Rocky Mountain districts to about 75° along the Gulf coast and in the lower Colorado River Valley. In practically all the important agricultural sections of the United States it is over 50°

Figures 50 and 51 show the highest and the lowest mean August temperatures in the 28-year period 1895–1922. The range in variation in this mean August temperature does not differ materially from that for July, being mostly about 5° and less than 10° F. throughout practically the entire United States

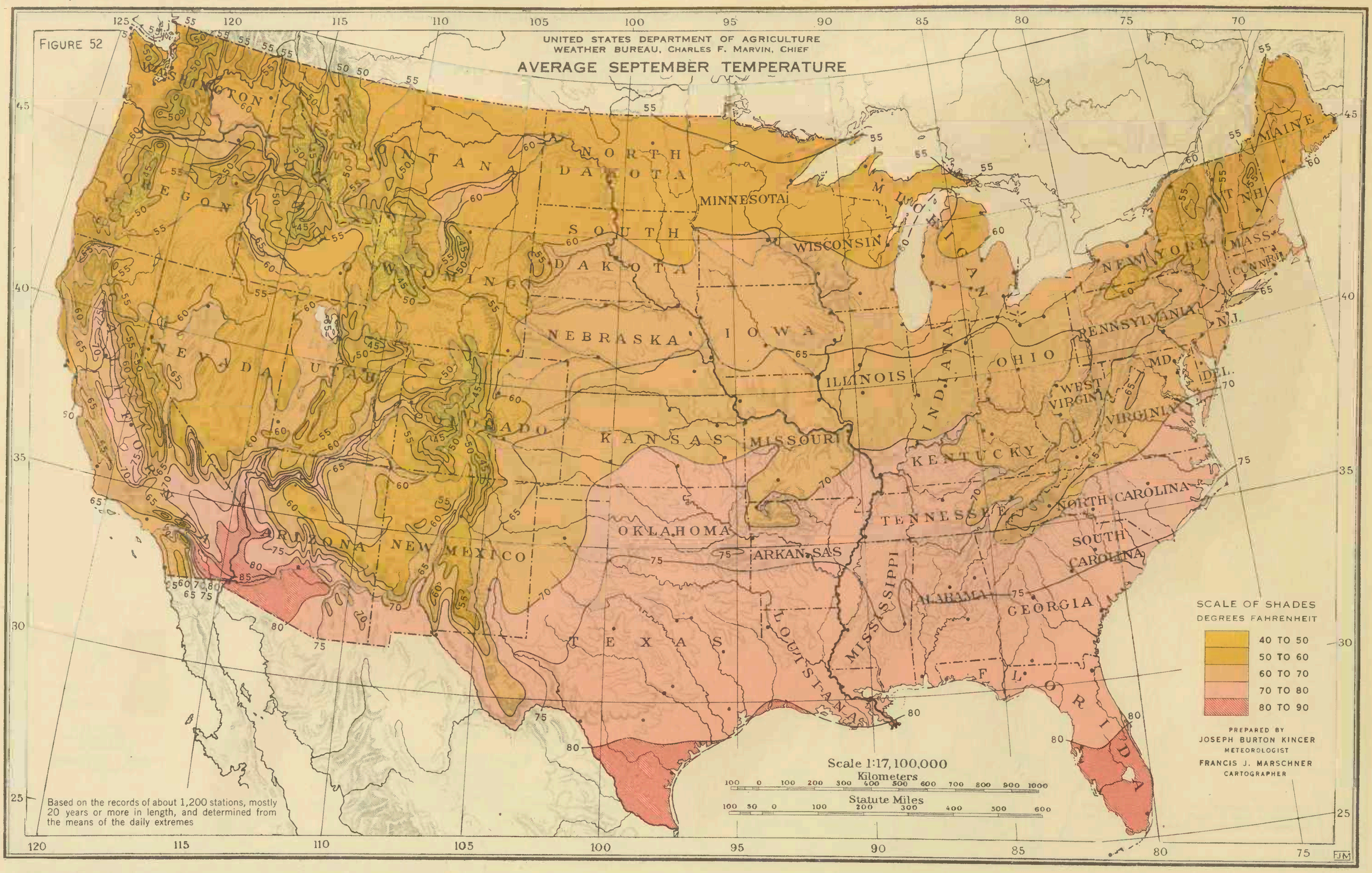
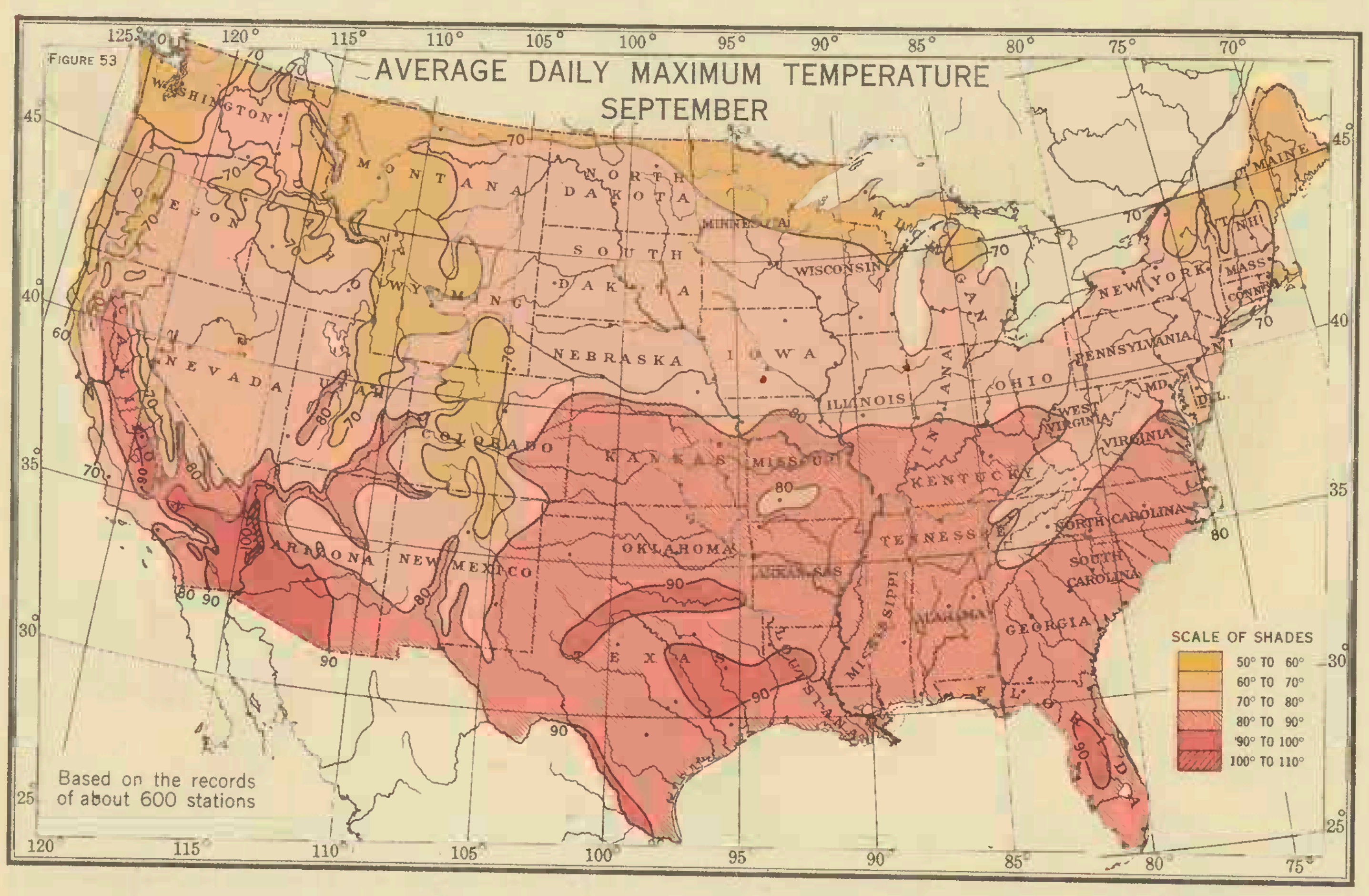
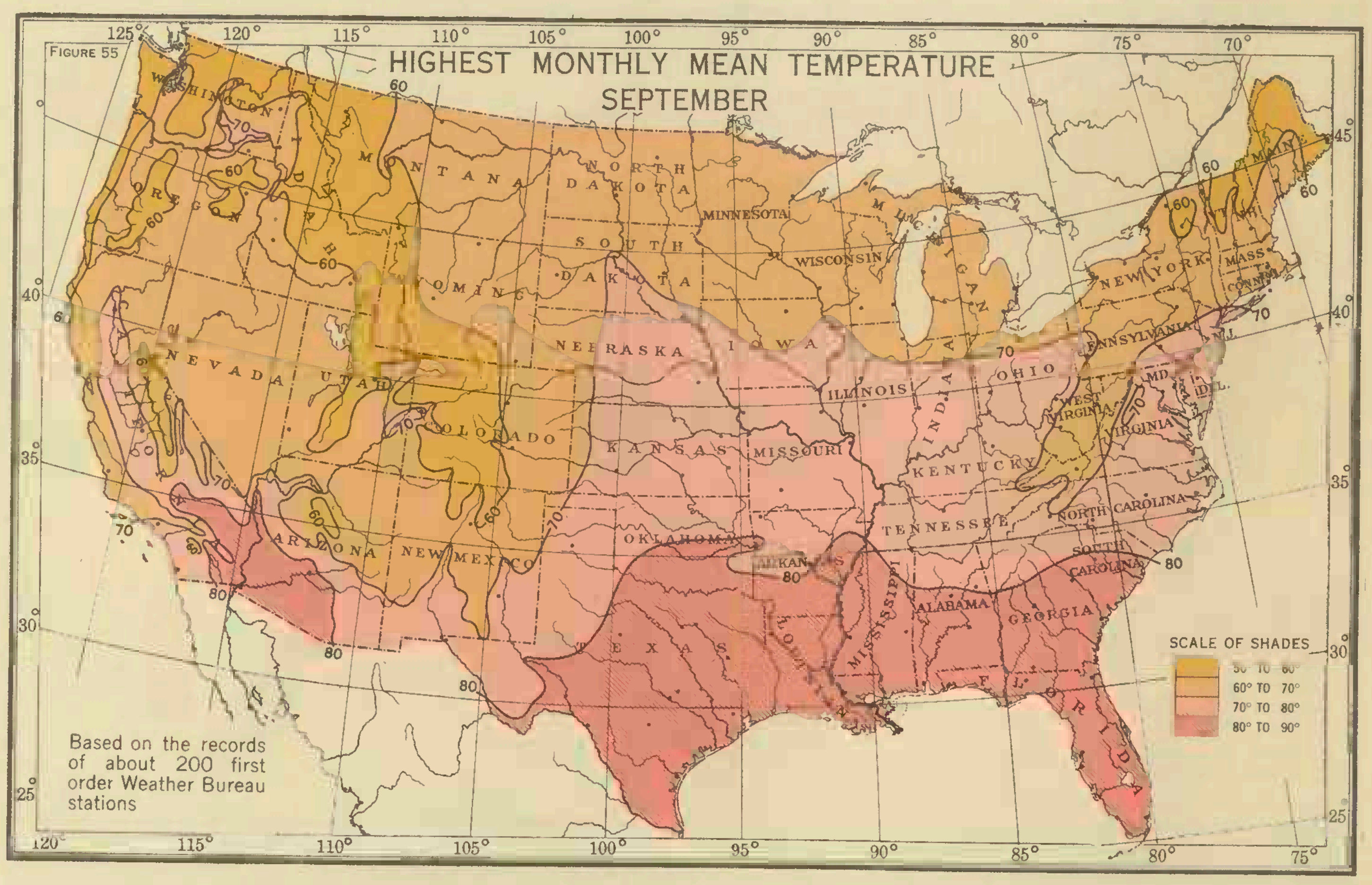
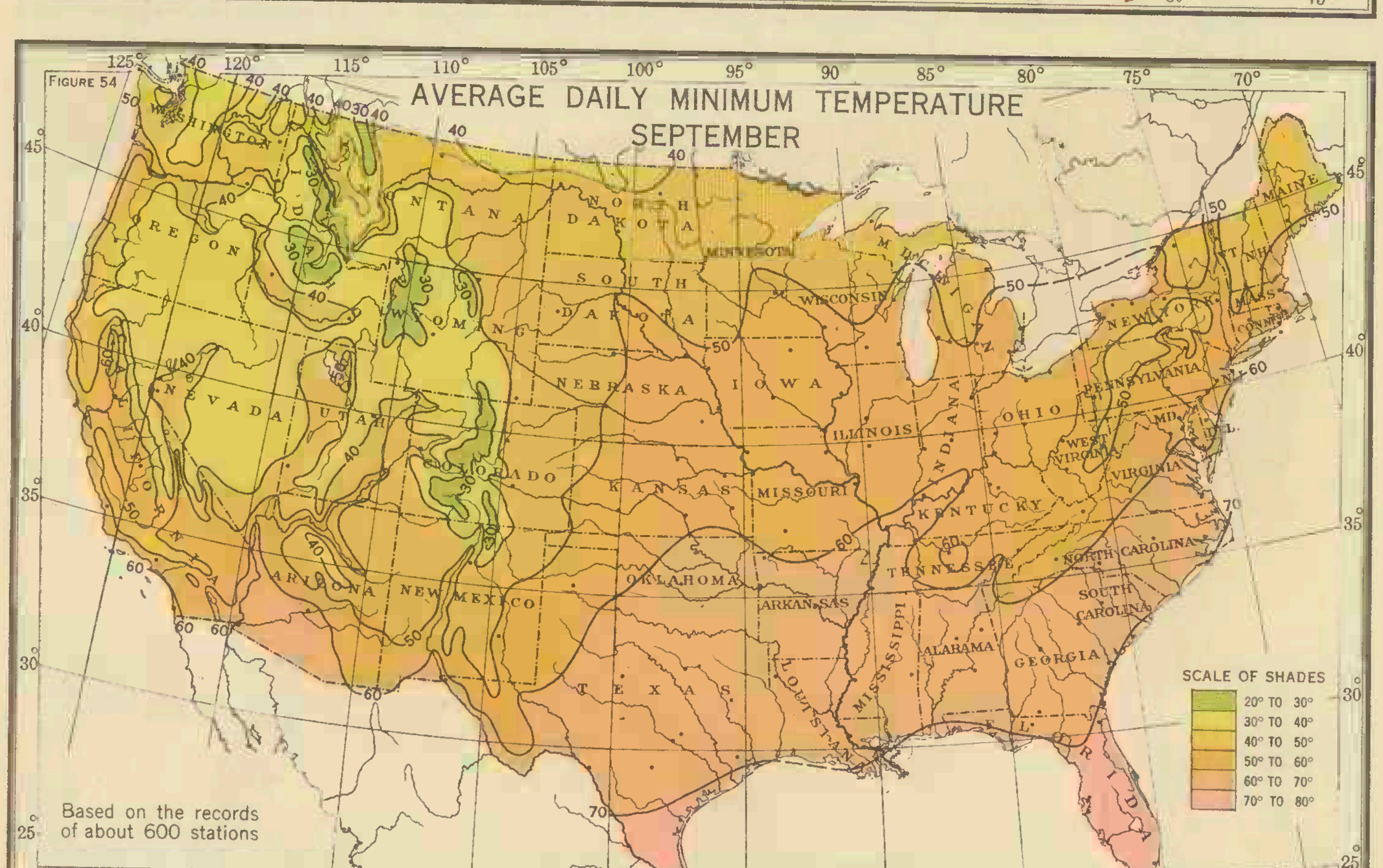
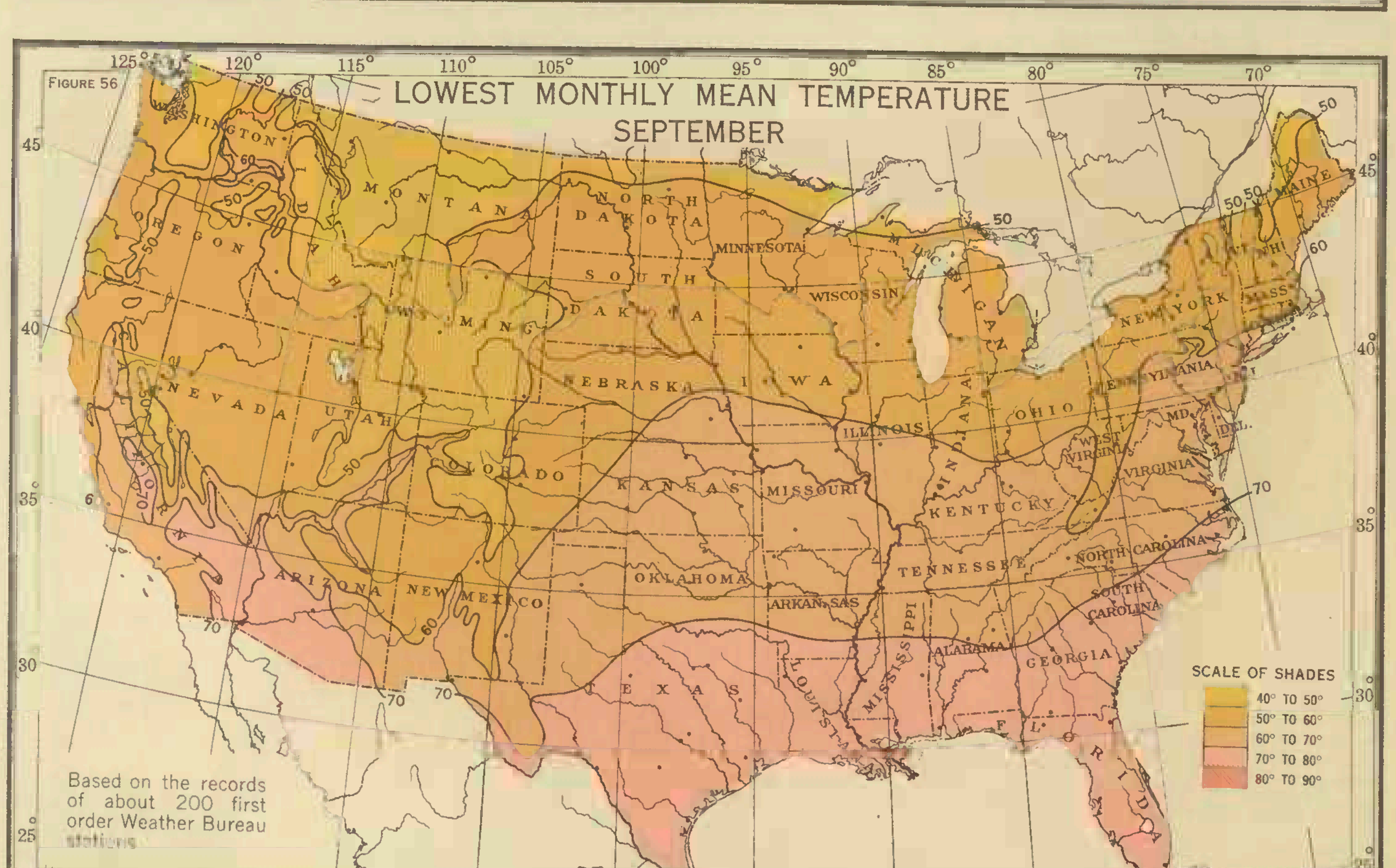


Figure 52.—The average September temperature east of the Rocky Mountains ranges from about 55° F. along the Canadian boundary, where it is about 8° lower than in August, to about 78° along the Gulf coast, where it is 2° or 3° lower. At the lower elevations of the Rocky Mountain and Interior Plateau regions the average September temperature varies mostly from 50° to 65°, but in the Great Valley of California it is 70° to 75° and in the lower Colorado River Valley 80° to 85°. In some localities along the immediate Pacific coast September is usually the warmest month in the year. High temperatures are experienced occasionally in September, especially between the Rocky Mountains and the Mississippi River, where records of 100° or higher are quite general. Likewise, in the interior valleys of California, high temperatures sometimes occur in this month, the highest being 110° in the southern portion of the Great Valley. Cool weather may also occur in September, freezing temperatures having been recorded as far south as the Ohio River and the southern portions of Kansas and Missouri; but east of the Rocky Mountains frost does not usually occur in September south of the northern border States









Figures 53 and 54 show for September the average daily maximum and the average daily minimum temperatures. East of the Rocky Mountains the average daily maximum for September ranges from about 65° F. in the extreme northern portion of Michigan and on the eastern Maine coast to about 88° along the Gulf coast and 95° in the lower Rio Grande Valley. West of the Rockies it varies from about 60° along the north Pacific coast to somewhat more than 100° in the lower Colorado River Valley. The average daily minimum east of the Rockies ranges from about 40° in the extreme northern portions of North Dakota and Montana to about 70° along the Gulf coast, and in the West it varies from less than 30° in the higher altitudes of the central and northern Rocky Mountain region to nearly 70° in the lower Colorado River Valley

Figures 55 and 56 show the highest and the lowest mean September temperatures in the 28-year period 1895–1922. The range of variation in mean September temperatures is somewhat larger than for August, being mostly between 8° and 15° F. in the principal agricultural areas

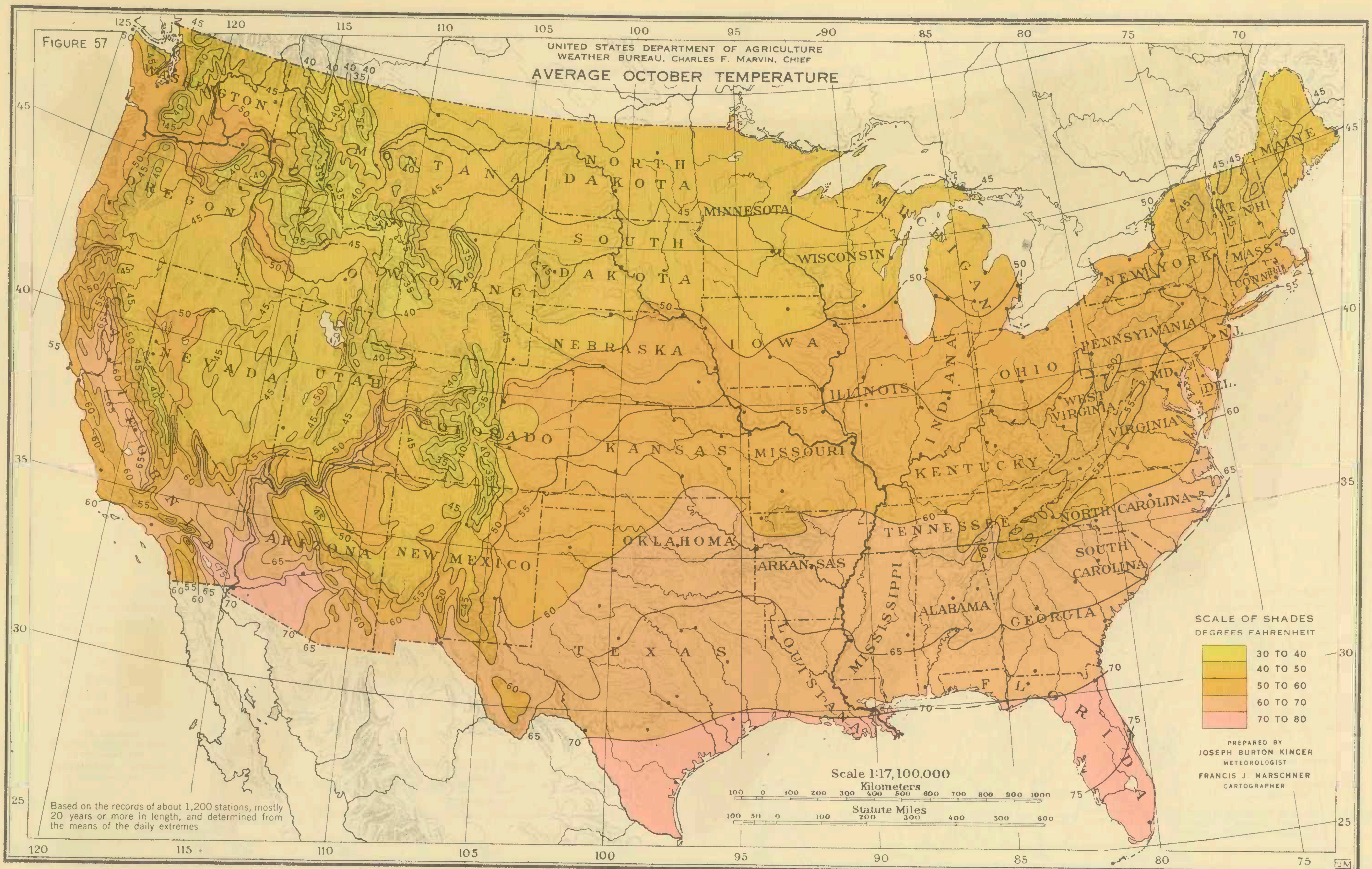
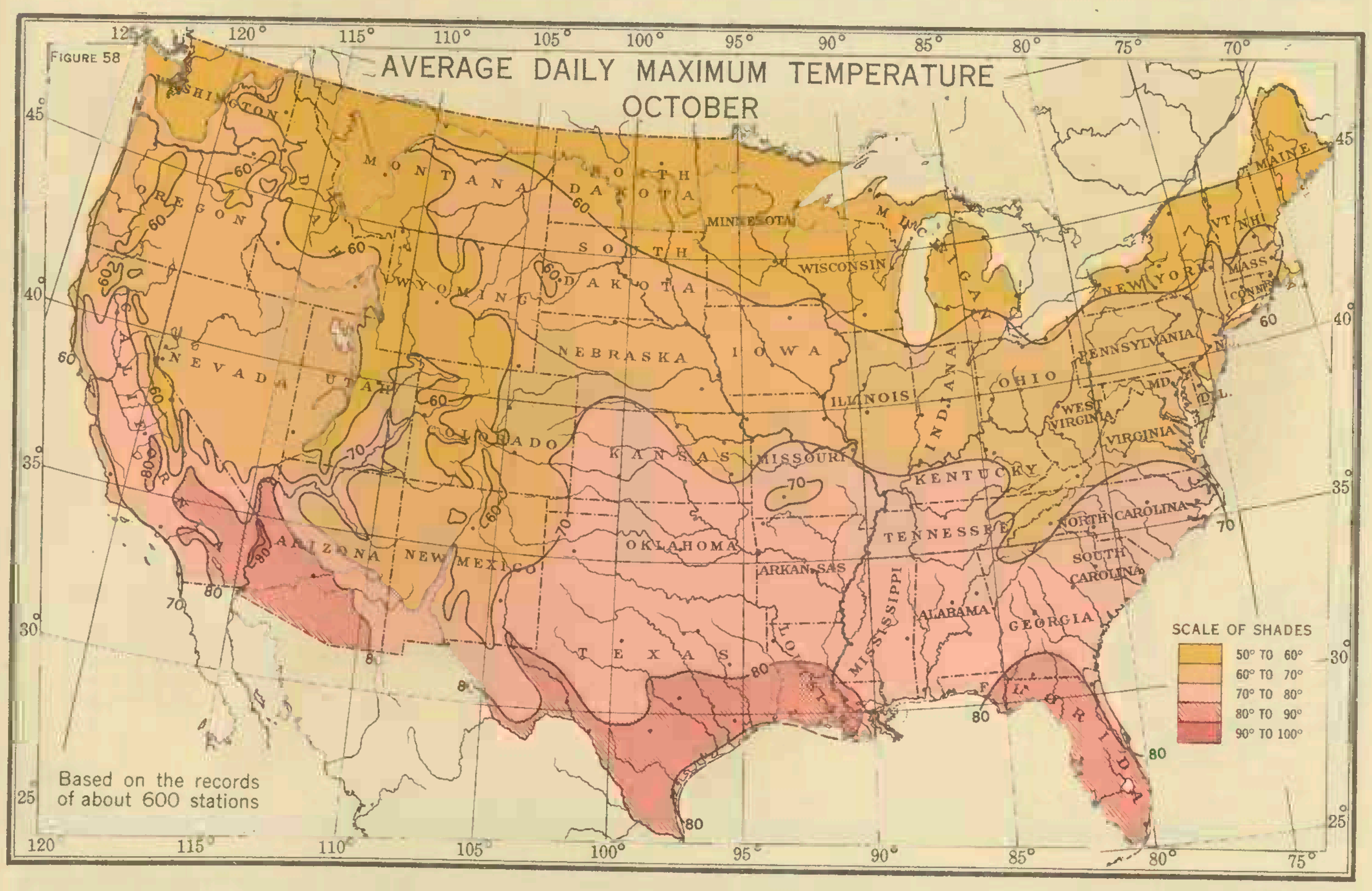
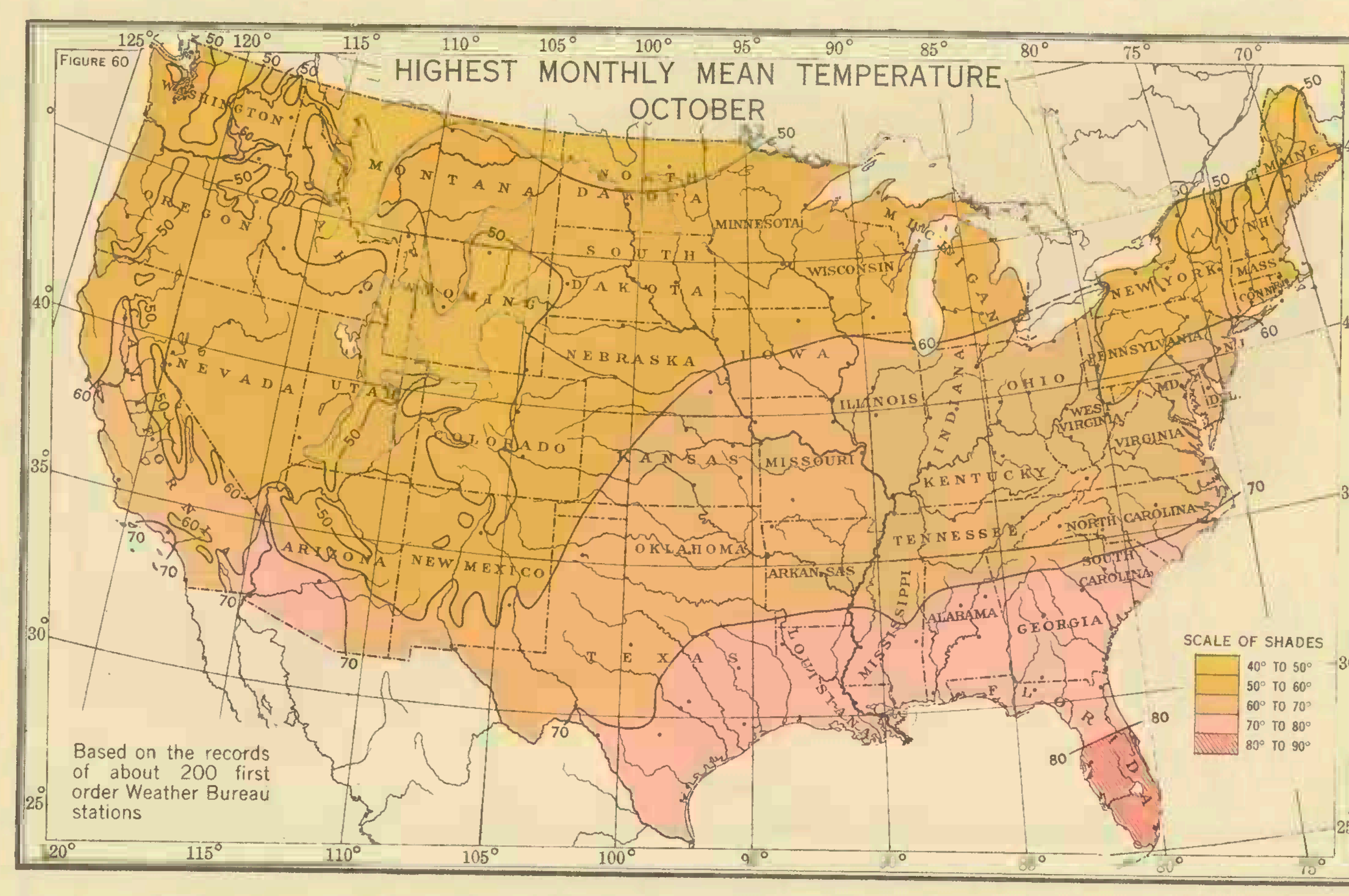
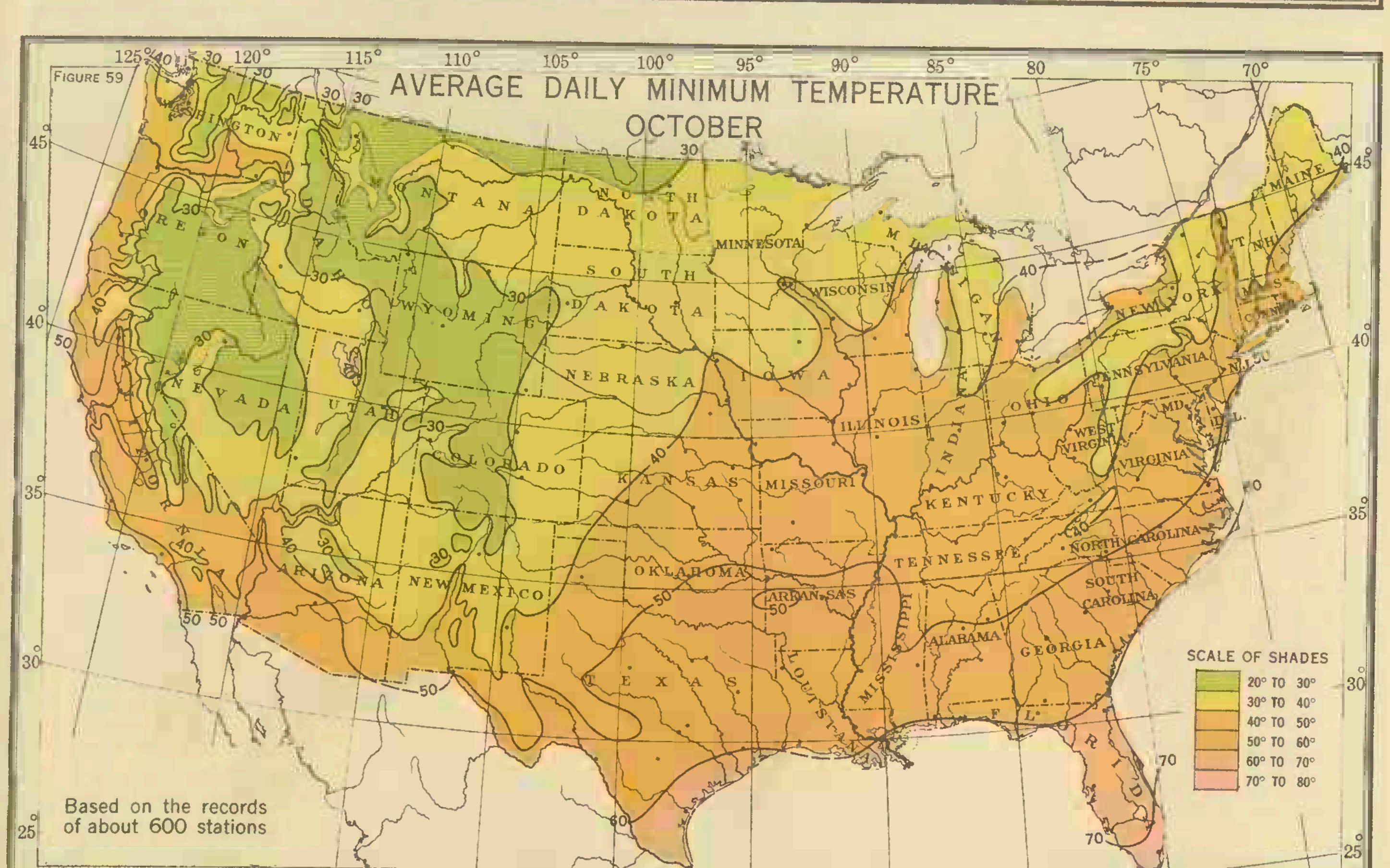
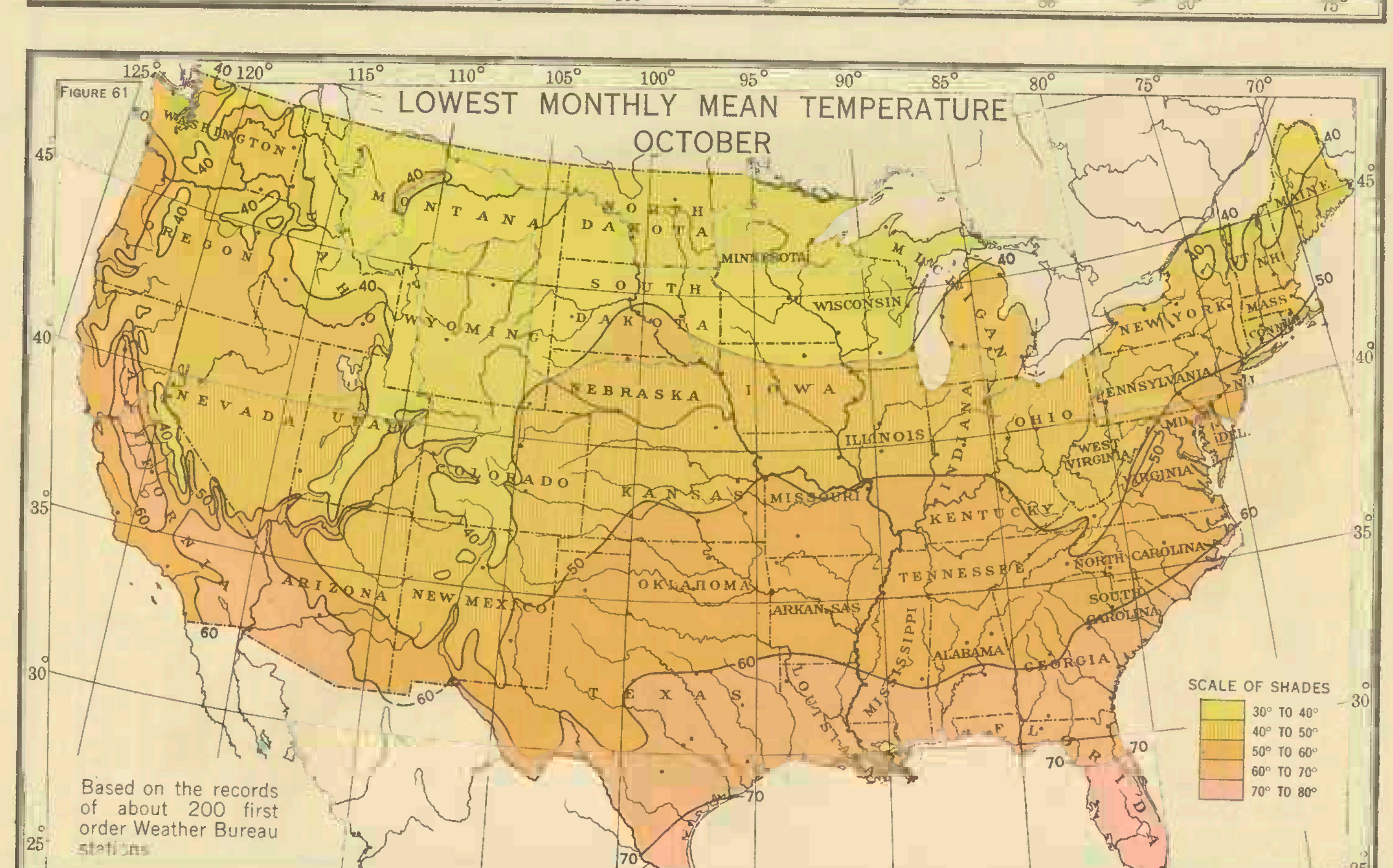


Figure 57.—During October there is a pronounced decrease in temperature, except in southern Florida and along the Pacific coast. The decrease below the average September temperature is in general from 10° to 15° F. East of the Rocky Mountains the average temperature for October ranges from about 45° along the northern border of the country to 70° on the Gulf coast. In the Rocky Mountain and Interior Plateau regions, at the lower elevations mostly, it varies from 40° to 50°, but is 10° to 20° higher in the valleys of New Mexico, Arizona, and California. Along the immediate Pacific coast the average temperature increases from about 50° at the north to 60° at the south. Temperatures below zero have been experienced at a few points in the North Central States in October, the lowest of record at a regular station of the Weather Bureau being −16° in northern Montana. Freezing temperatures have occurred in this month nearly to the Gulf coast. In a normal year freezing weather occurs before the last of October as far south as the northern portions of South Carolina, Georgia, Alabama, and Mississippi and the central portions of Arkansas and Oklahoma. Along the Canadian border freezing temperatures occur, on the average, on about 15 days in October, but to the southward the number decreases rapidly









Figures 58 and 59 show for October the average daily maximum and the average daily minimum temperatures. East of the Rocky Mountains the average daily maximum ranges from about 55° F. in the northern portions of New England, Michigan, Wisconsin, and Minnesota to nearly 90° in the lower Rio Grande Valley, and in most districts is about 10° lower than for September. In the West it varies from about 55° in the central and northern Rocky Mountain districts to 90° in the lower Colorado River Valley. The average daily minimum ranges from about 20° in the higher altitudes of the Rocky Mountain region to about 60° along the central Gulf coast. In the Corn Belt the average of the daily minima for October ranges from about 40° in the northern portion to 50° in the southern

Figures 60 and 61 show the highest and the lowest mean October temperatures in the 28-year period 1895–1922. In the interior districts the range of variation in mean October temperatures during the 28-year period is mostly from 10° to 15°, but near the Atlantic, Gulf, and Pacific coasts it is smaller

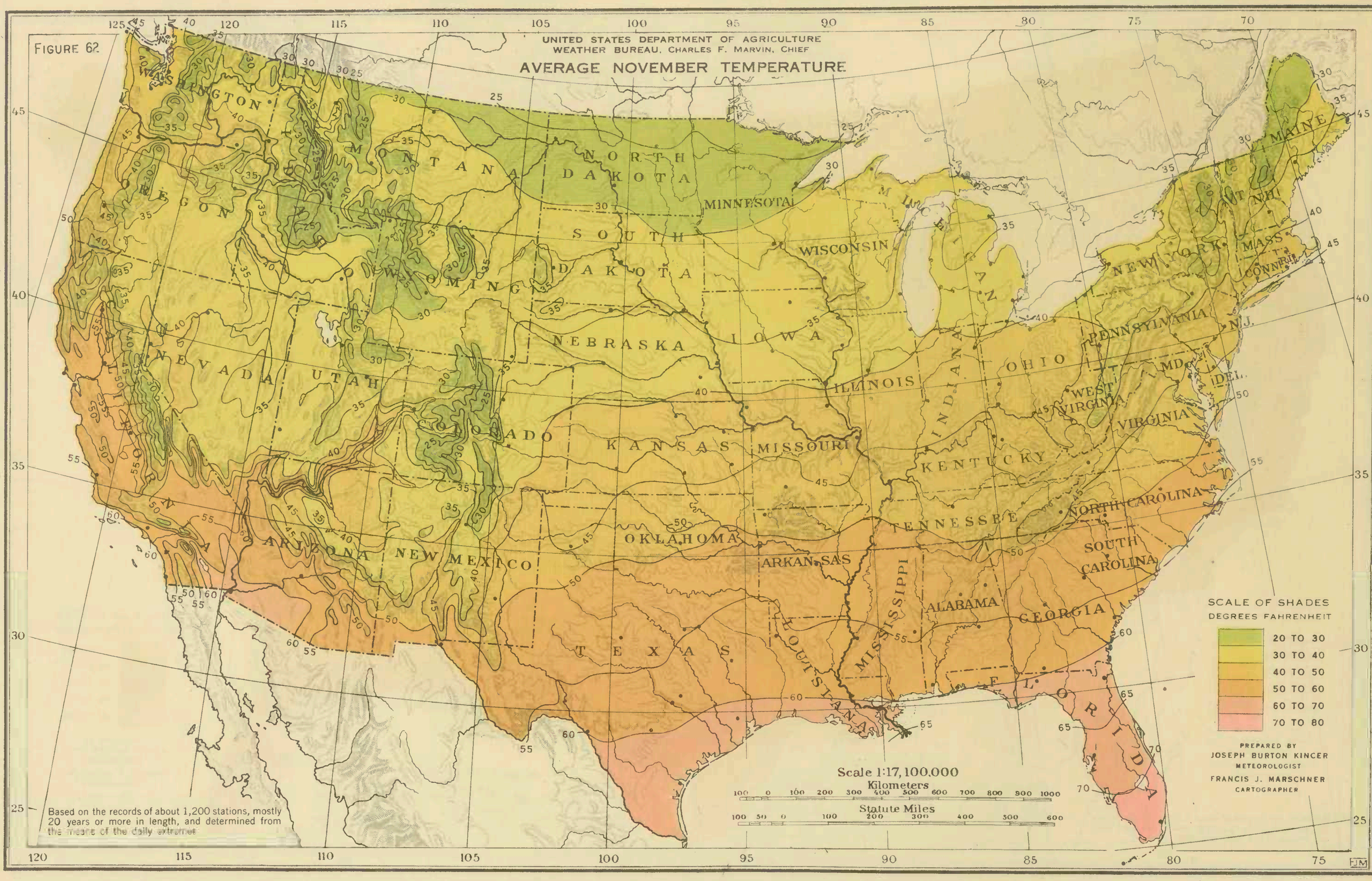
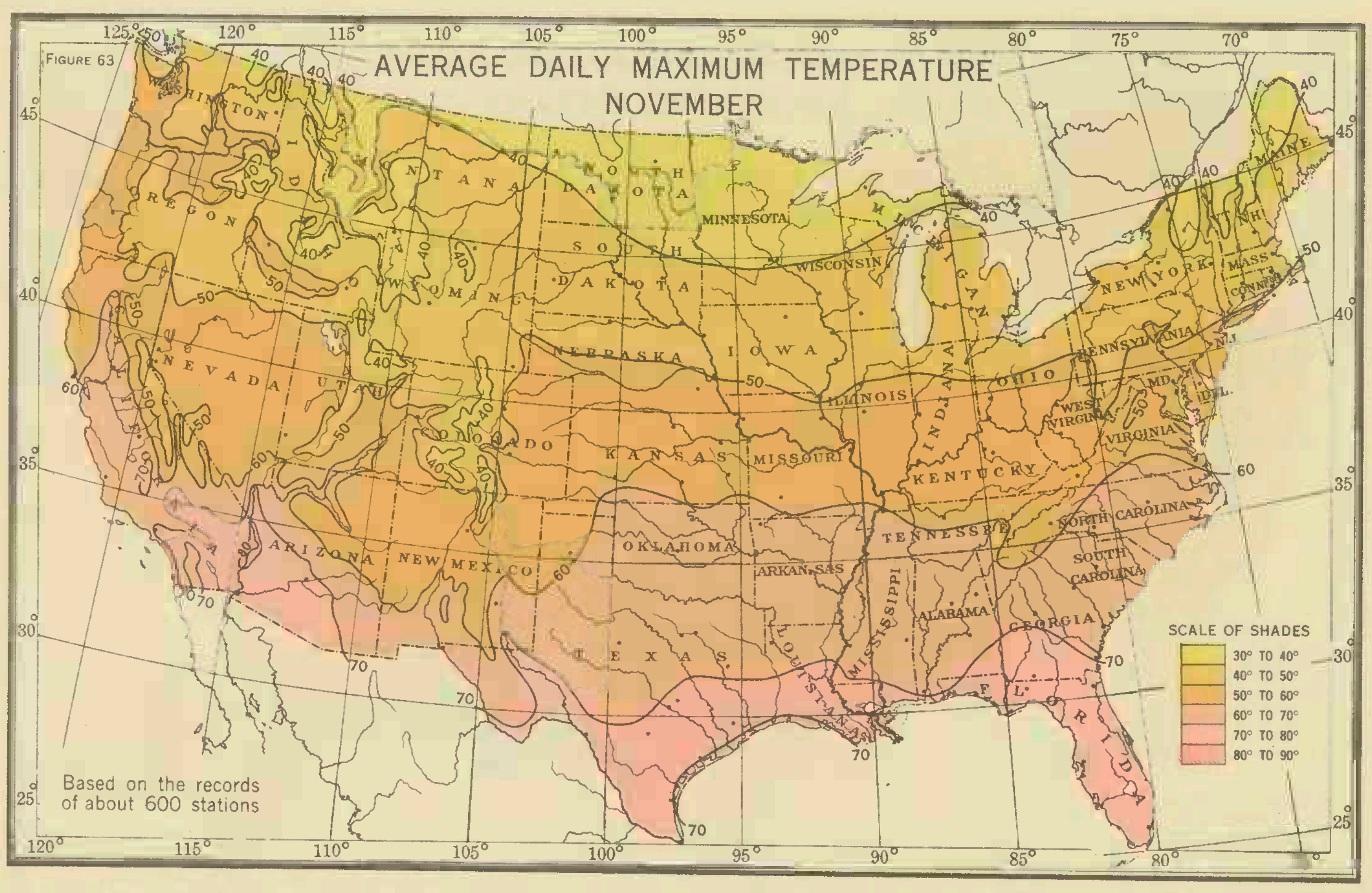
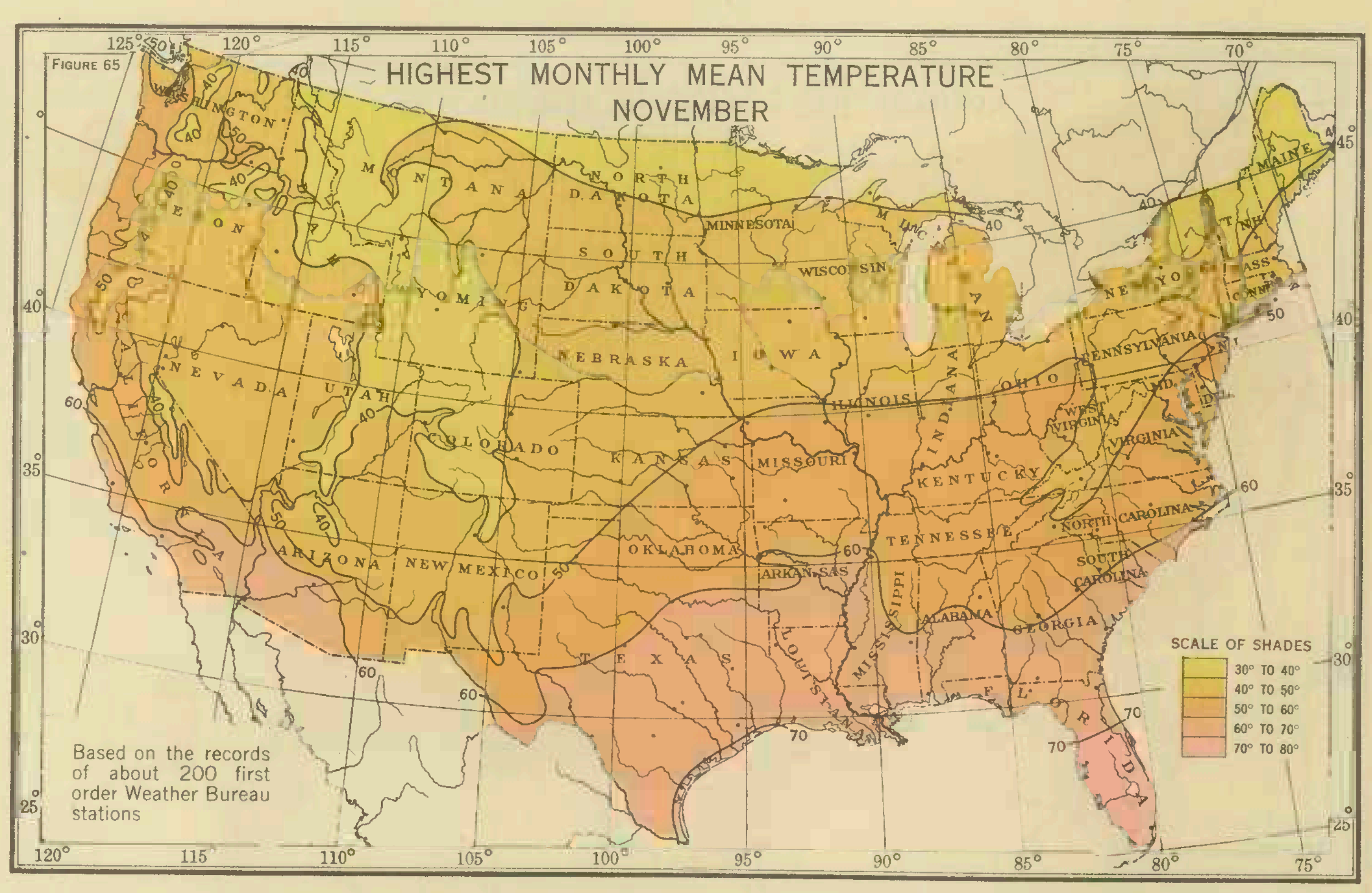
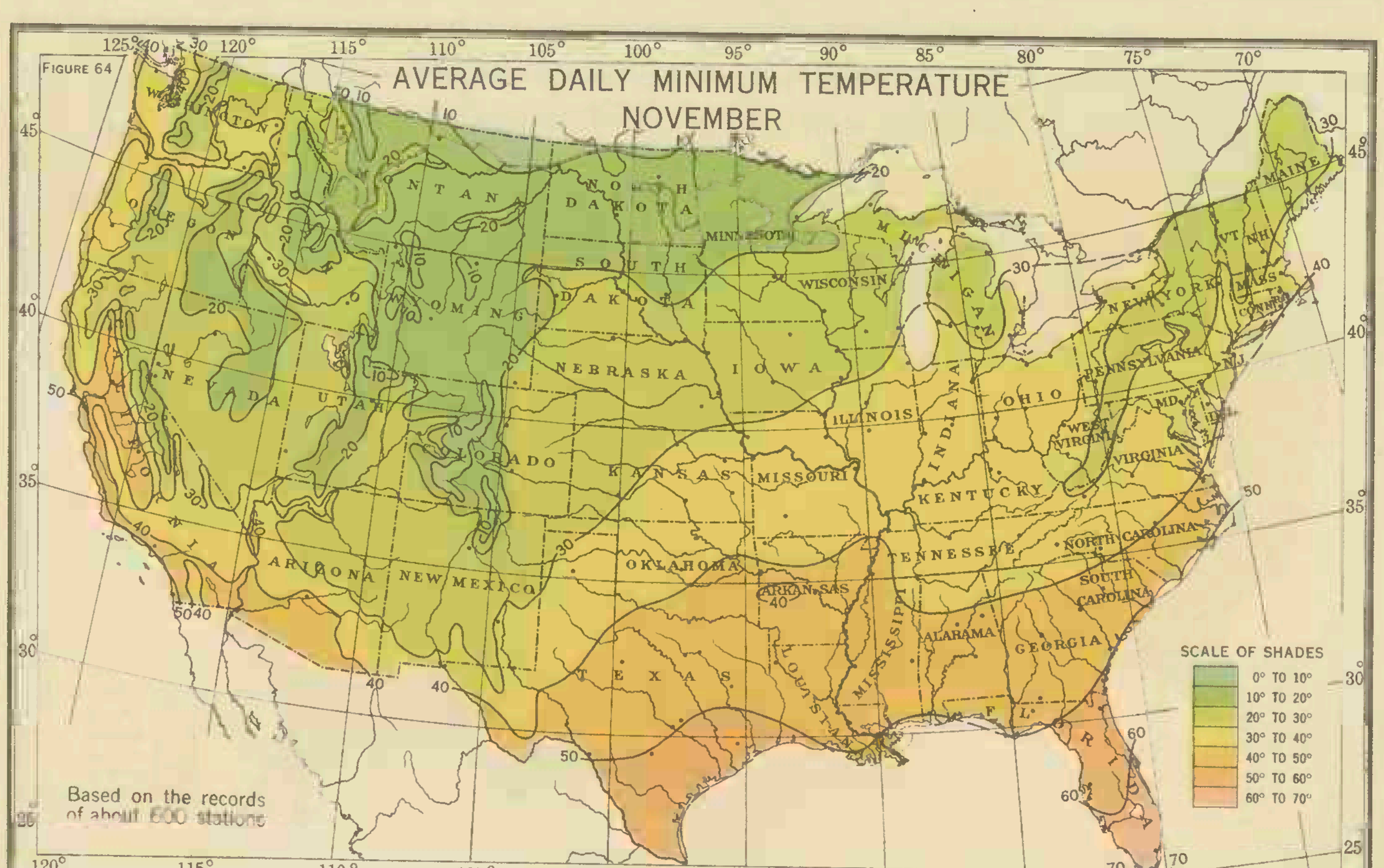
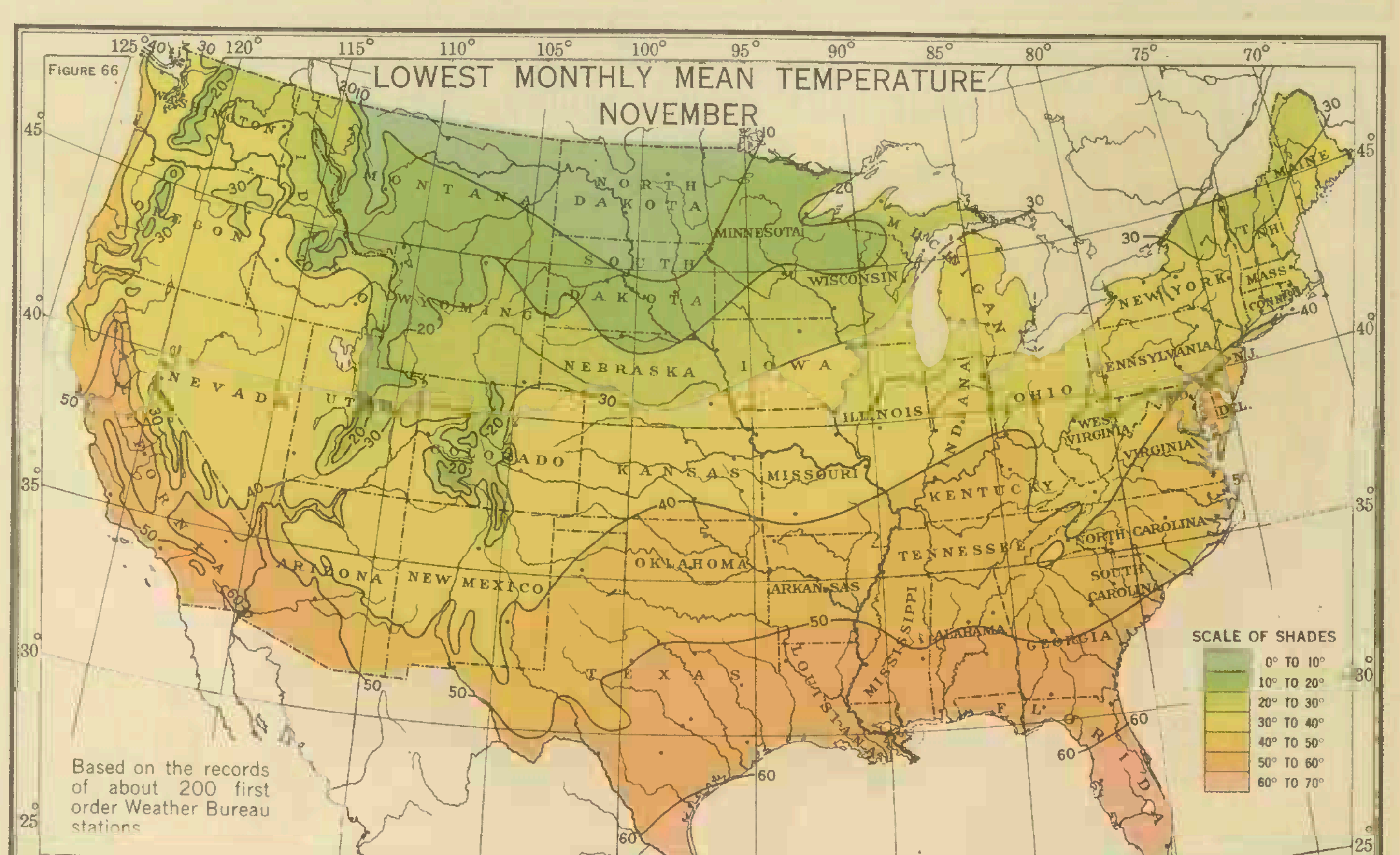


Figure 62.—During November the decrease in temperature, as a rule, is rapid, the average temperature for the month being usually from 10° to 20° F. lower than that for October, except along the Gulf and Pacific coasts. The greatest decrease in temperature is in Minnesota and the Dakotas. East of the Rocky Mountains the average November temperature ranges from about 25° in northern Minnesota and North Dakota to about 60° along the Gulf coast, and 70° in southern Florida. Along the Pacific coast it increases from 45° at the north to about 60° at the south. In November cold waves of considerable severity sometimes advance from the Canadian Northwest and overspread the north Central States, but they usually lose force rapidly after entering the United States and are seldom of long duration. Zero temperature has never been experienced at a regular Weather Bureau station in this month south of the Ohio River, but freezing weather has occurred southward to Tampa, Fla. Freezing temperatures are not ordinarily reached in November, however, along the Texas coast nor south of Gainesville, Fla. The lowest temperature of record for this month at a regular reporting station is −33° in northern Montana









Figures 63 and 64 show for November the average daily maximum and the average daily minimum temperatures. East of the Rocky Mountains the average daily maximum ranges from about 35° F. along the north-central border of the United States to about 70° along the Gulf coast. Except along the Gulf and south Atlantic coasts it is 10° to 20° lower than for October. In the West the average daily maximum varies from less than 40° in the higher altitudes of the Rocky Mountain region to 80° in the lower Colorado River Valley. The average daily minimum for November ranges from about 10° in northern North Dakota, northeastern Montana, and in the higher altitudes of Colorado and Wyoming to about 50° along the central Gulf and southern California coasts, and nearly 70° in southern Florida

Figures 65 and 66 show the highest and the lowest mean November temperatures in the 28-year period 1895–1922. East of the Rocky Mountains the variation from year to year in mean November temperatures is large, particularly in the North Central States, where the range is as great as 30° F. or more. The coldest November on record occurred in North Dakota and eastern Montana in 1896, when the mean temperature for the month was about 7°

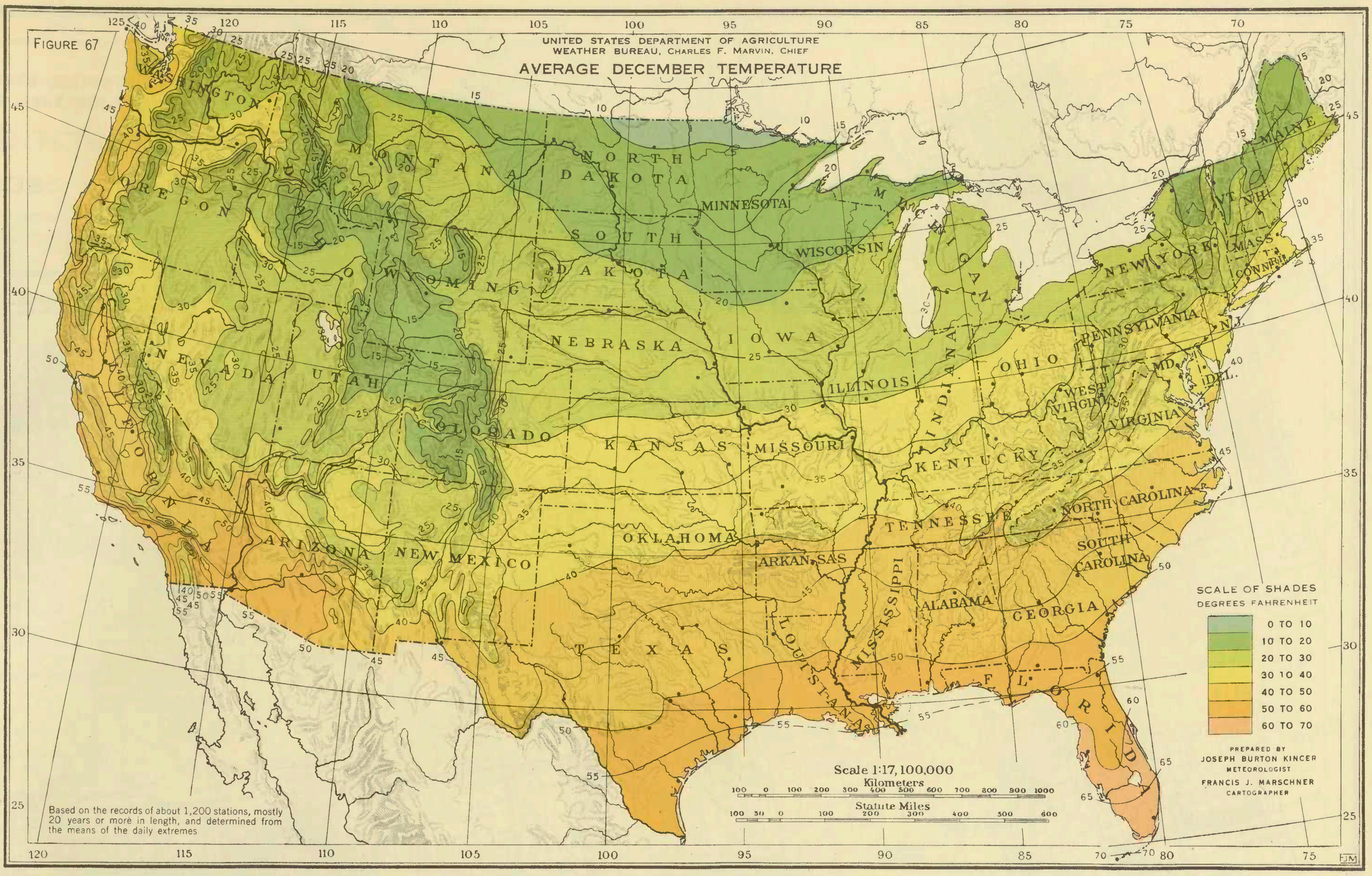
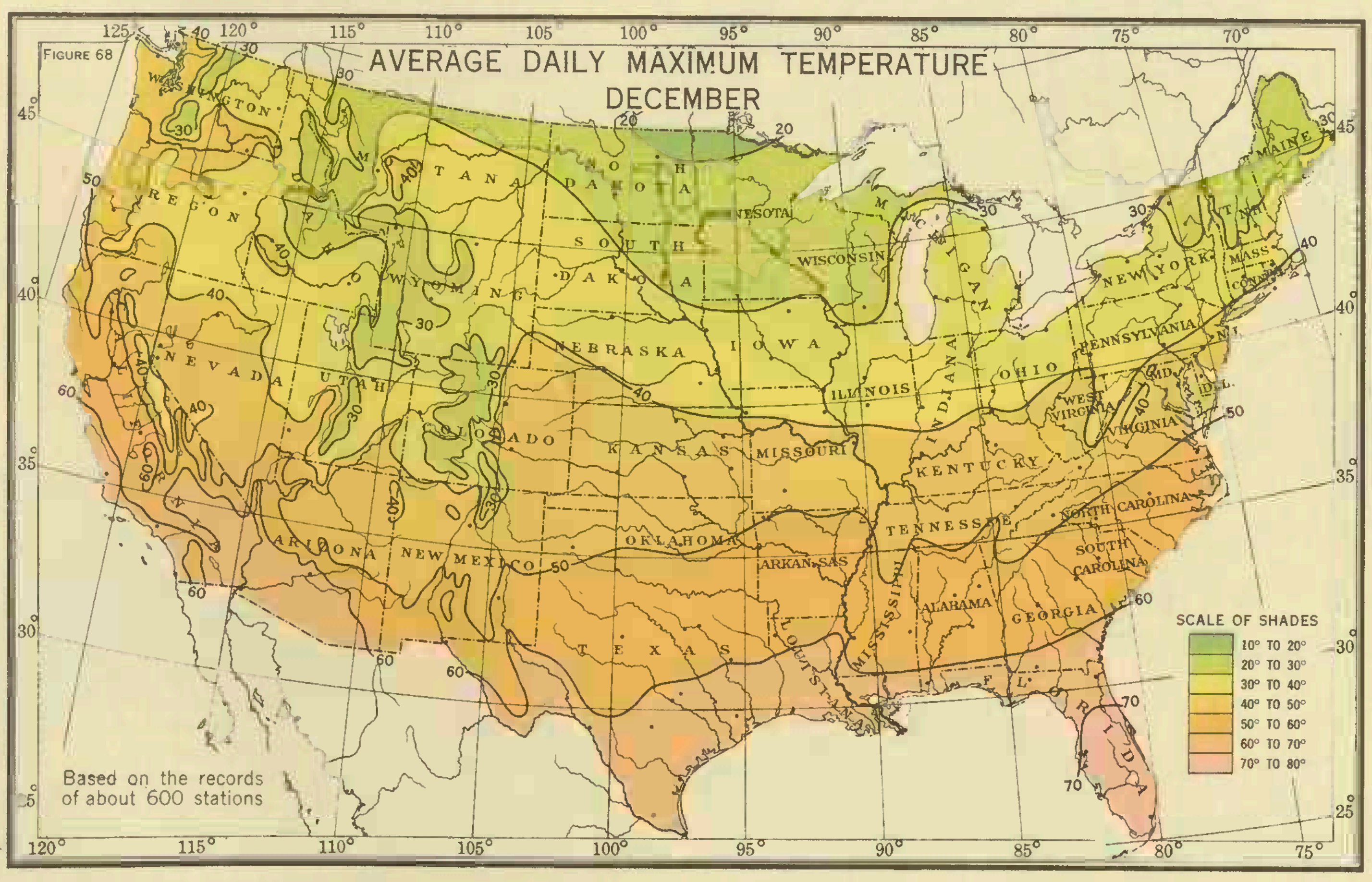
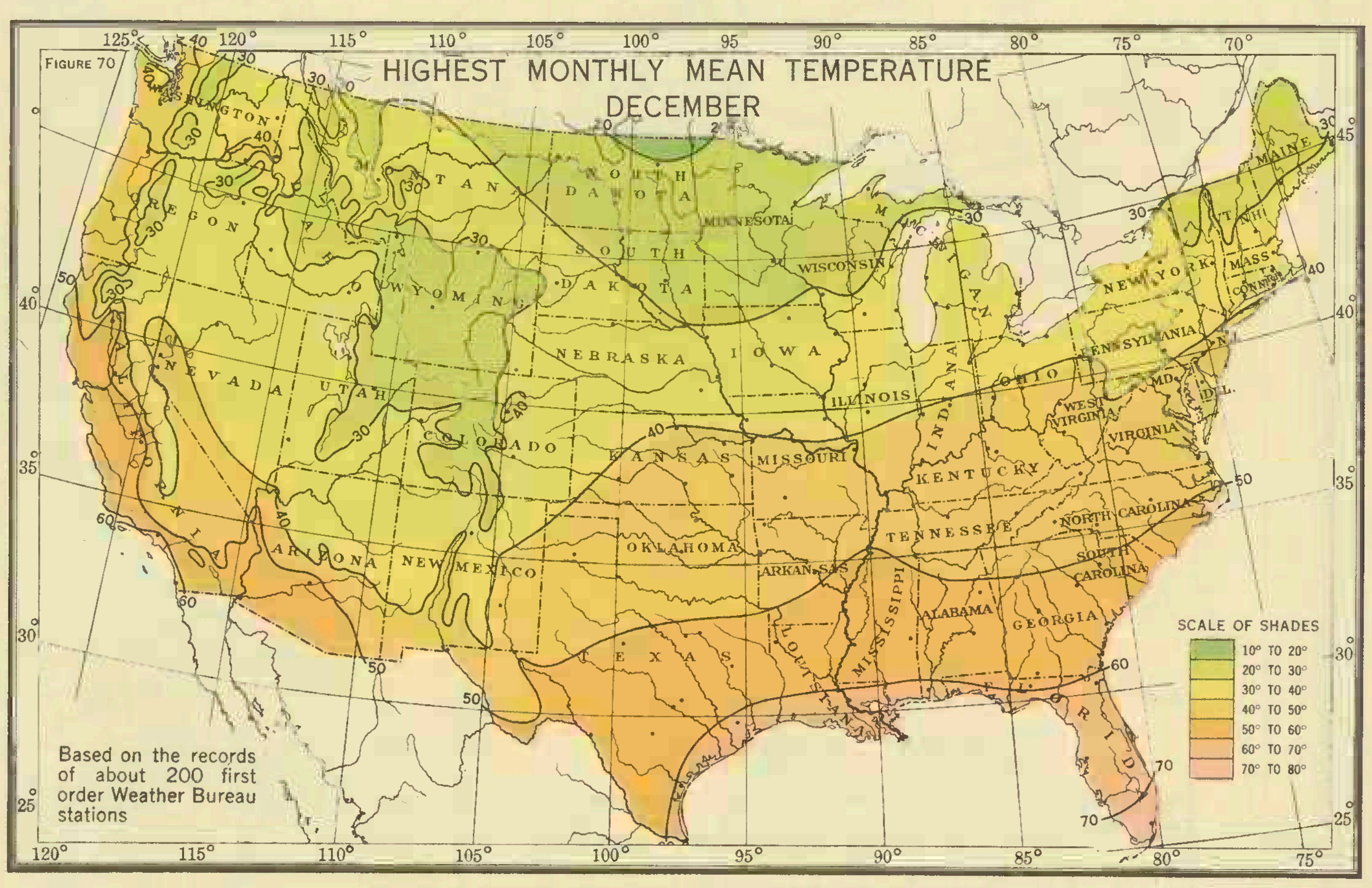
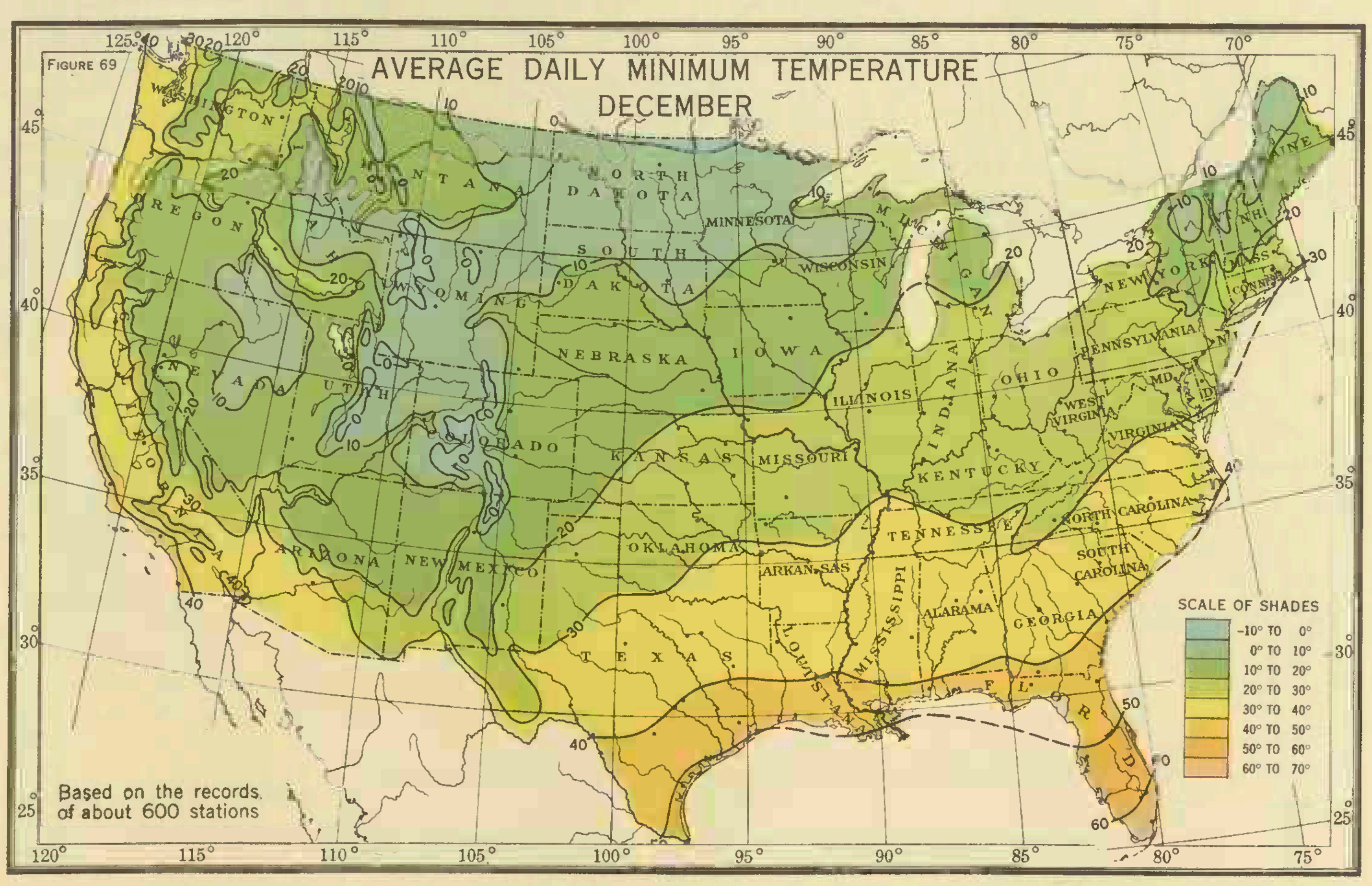
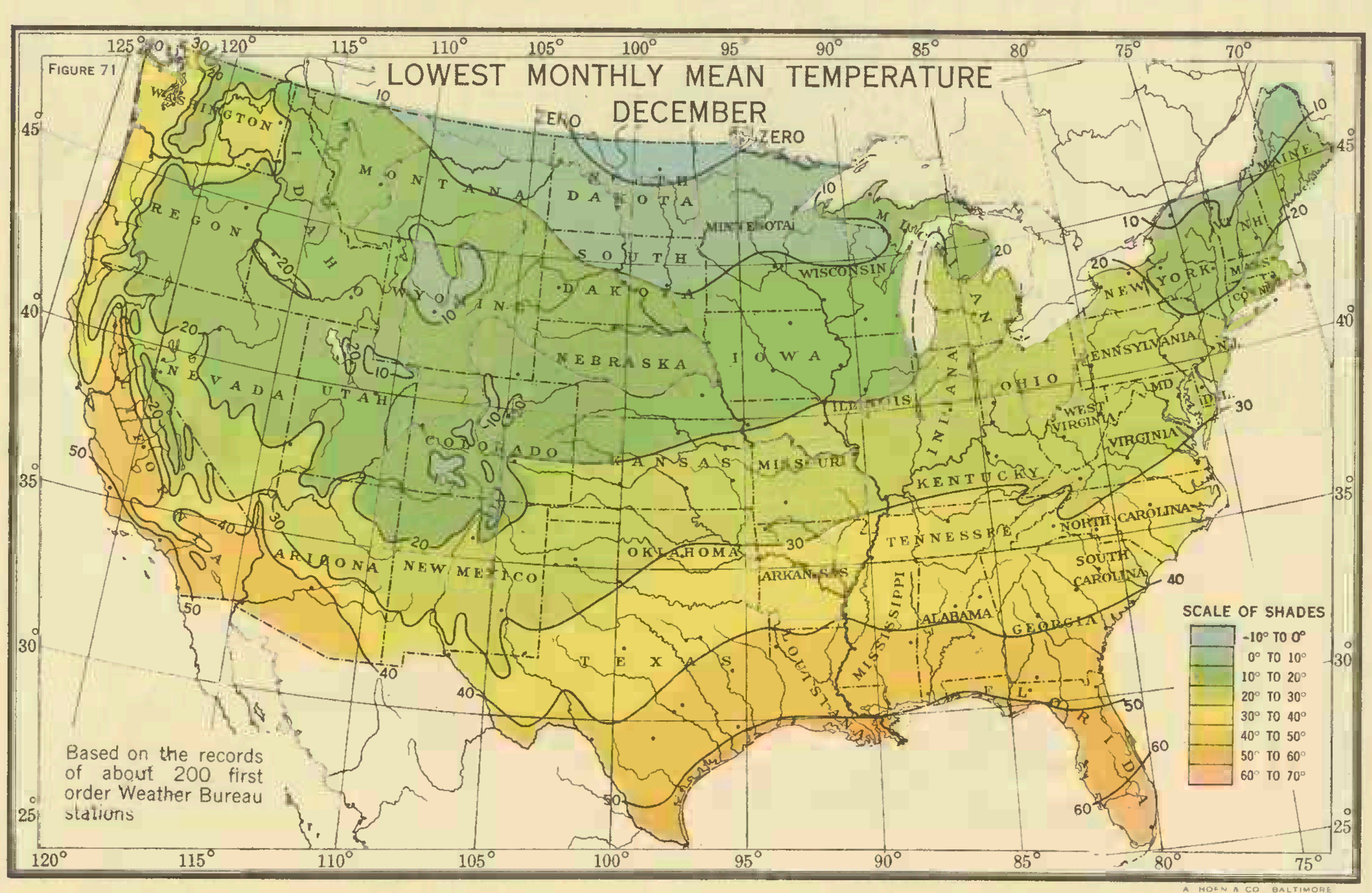


Figure 67.—During December the temperature, as a rule, continues to decrease rapidly. East of the Rocky Mountains the decrease in the average temperature from November to December ranges from about 15° F. in the northern border States to 7° or 8° along the Gulf coast. The average December temperature ranges from about 10° in northwestern Minnesota and northeastern North Dakota to 55° in the Gulf coast region, and 70° in extreme southern Florida. In the valleys of the Rocky Mountain and Interior Plateau regions the average temperature for the month varies from 20° to 35°, except in the Mexican-border States, where it is locally as high as 55°. Along the Pacific coast the average temperature increases from about 44° at the north to 56° at the south. During December cold waves become more frequent and severe, and in the interior portions of the country very low temperatures occasionally occur. The lowest of record for this month at a regular Weather Bureau station is −50° in northern Montana. Temperatures of −10° to −15° have been experienced in December as far south as southern Kansas and Missouri and −5° in portions of Tennessee and North Carolina. Along the central Gulf coast the lowest temperature recorded in December is 14°









Figures 68 and 69 show for December the average daily maximum and the average daily minimum temperatures. East of the Rocky Mountains the average daily maximum ranges from about 20° F. in northern Minnesota and North Dakota to about 65° along the Gulf coast, and 70° in southern Florida and extreme southern Texas. In the West it varies from less than 30° in the central Rocky Mountain region to nearly 70° in the lower Colorado River Valley. The average of the daily minima for December east of the Rockies ranges from about zero in northern Minnesota and North Dakota to 66° at Key West, Fla. In the West it varies from below zero at the higher altitudes in the Rocky Mountain region to 48° on the coast of southern California, decreasing slowly along the coast northward to 46° at San Francisco and 40° along the Washington coast

Figures 70 and 71 show for December the highest and the lowest mean temperatures in the 28-year period 1895–1922. The variation from year to year is comparatively large in most districts. The range is 15° to 20° F. in the central and northern Rocky Mountain districts and in the North Central States, about 10° in the Gulf coast region, but only about 5° along the north Pacific coast

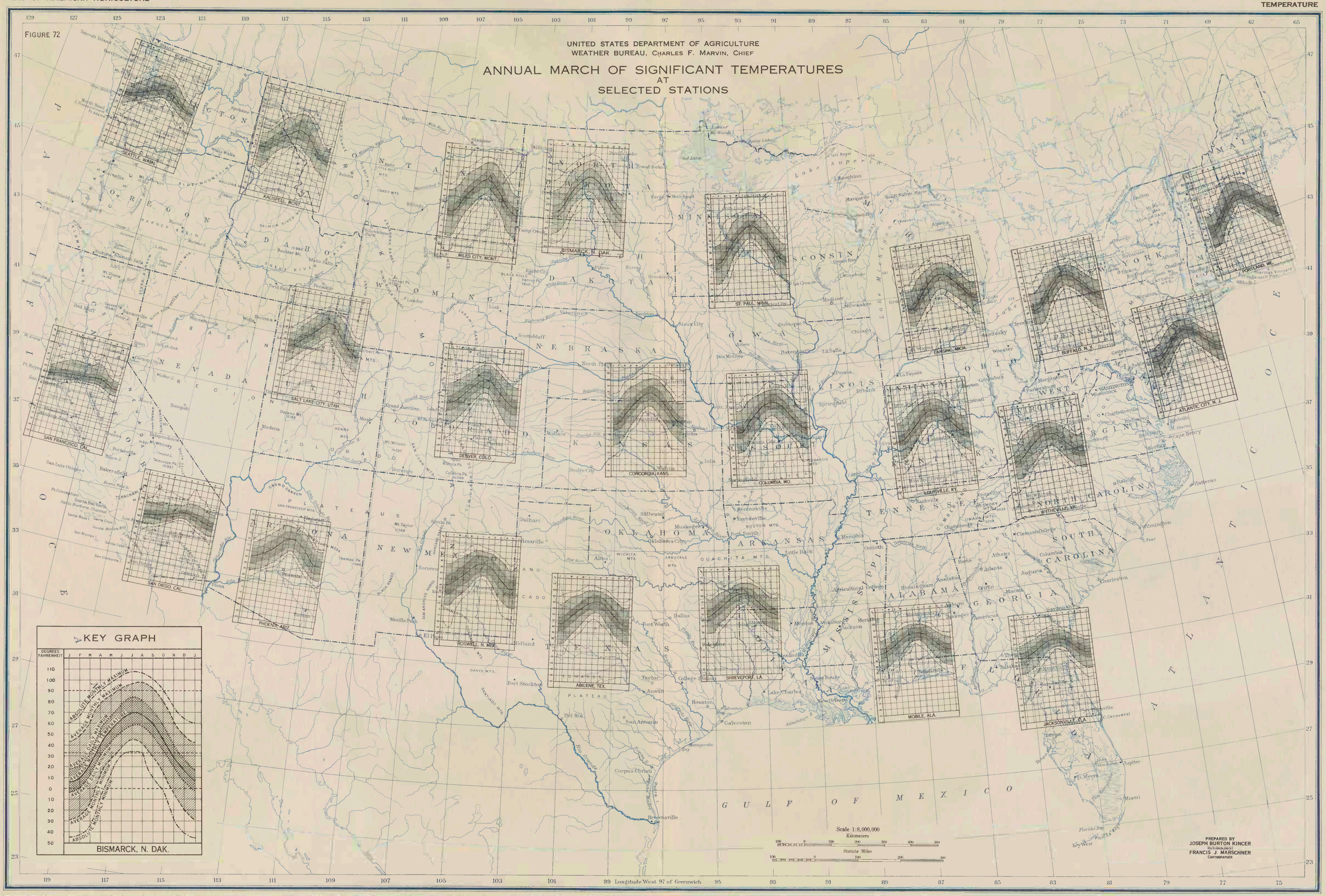
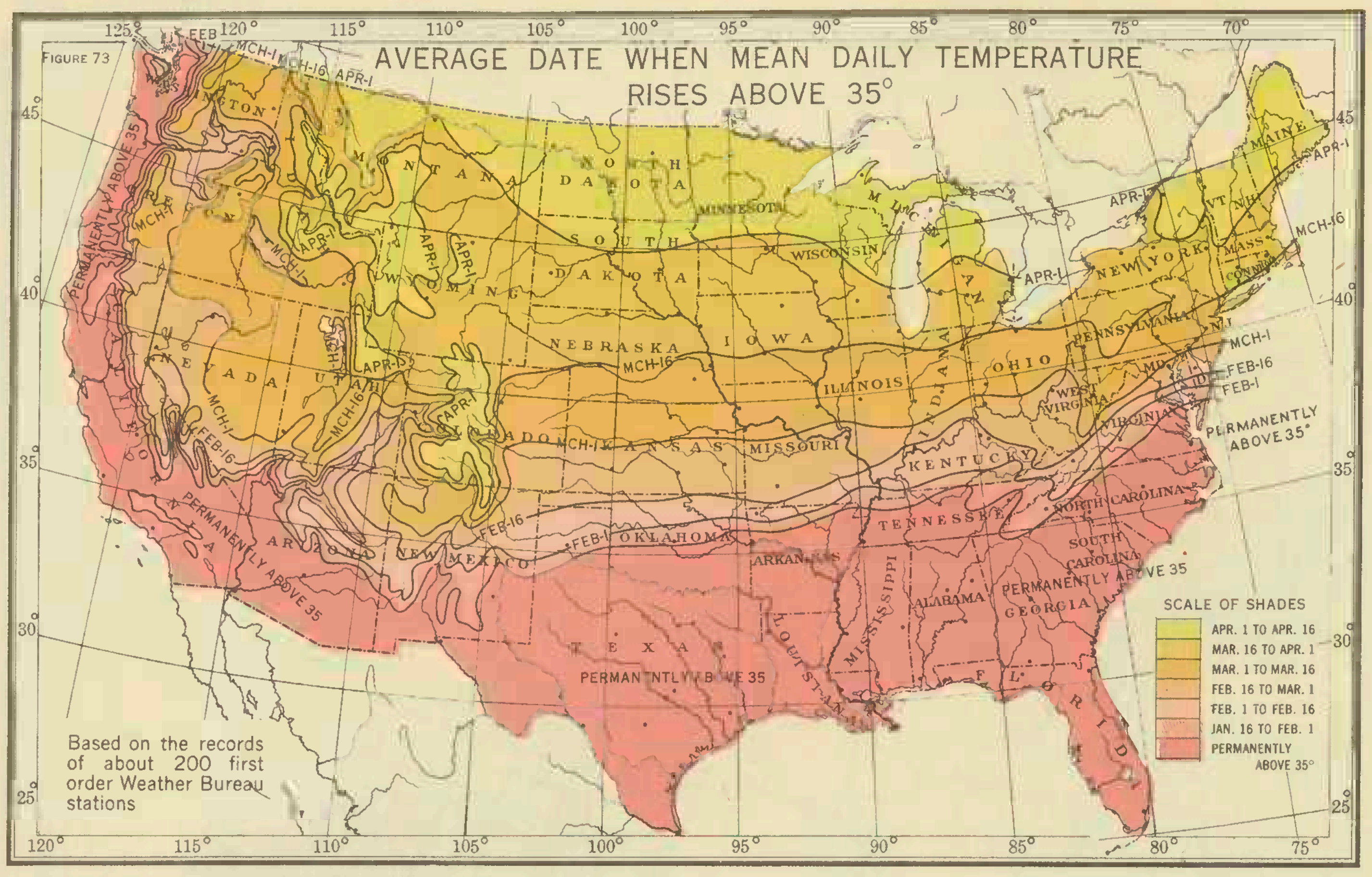
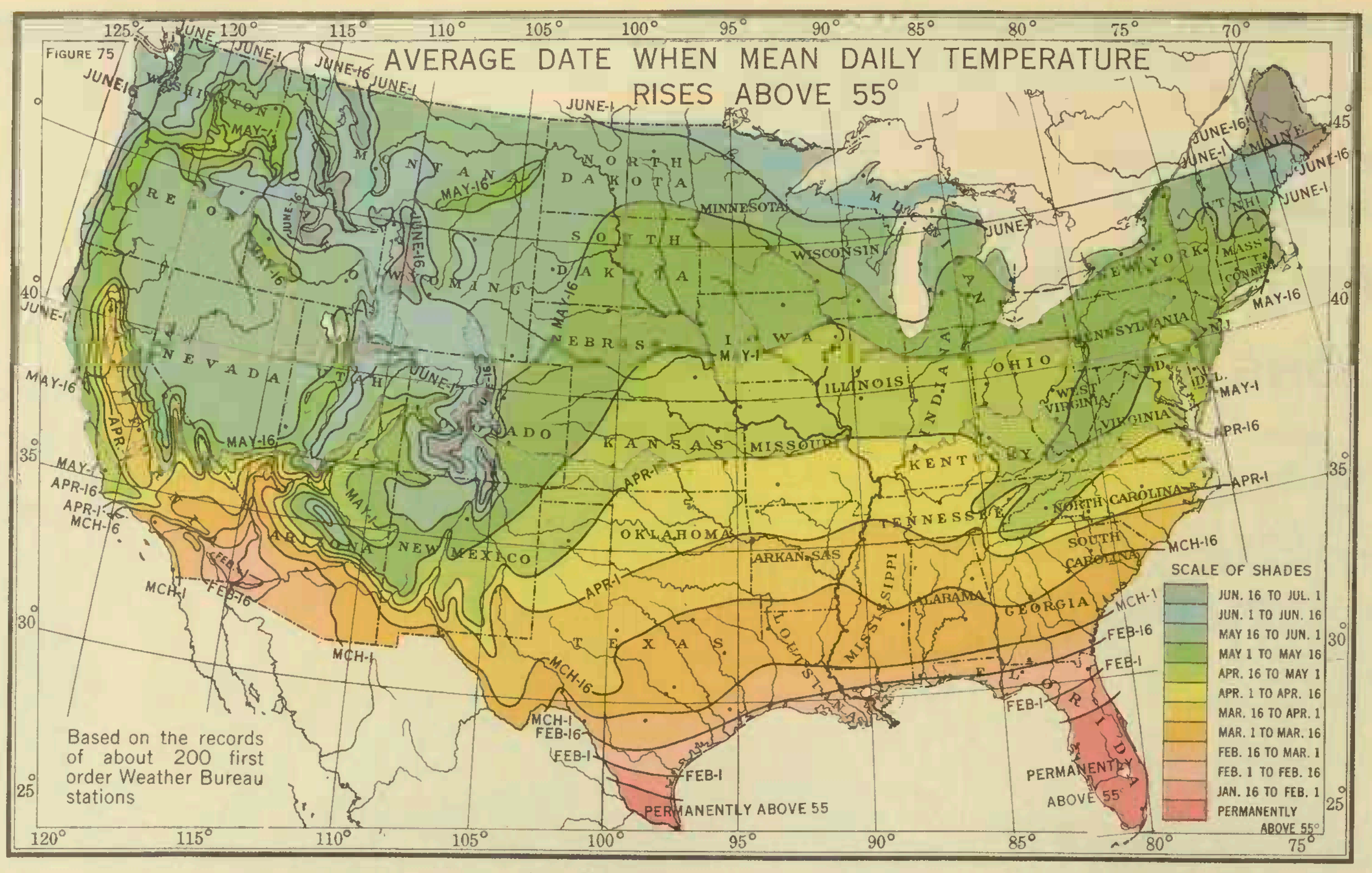
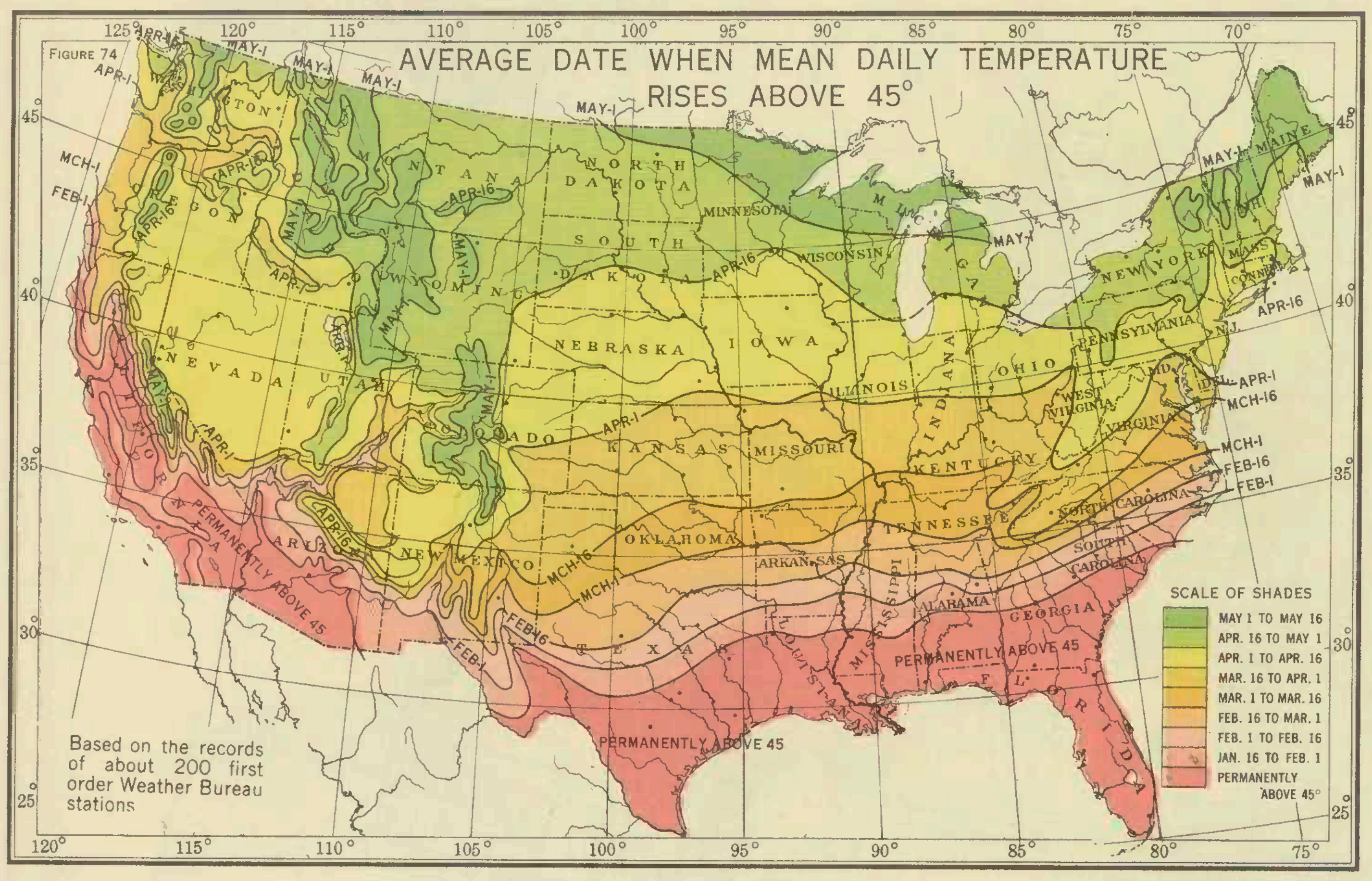
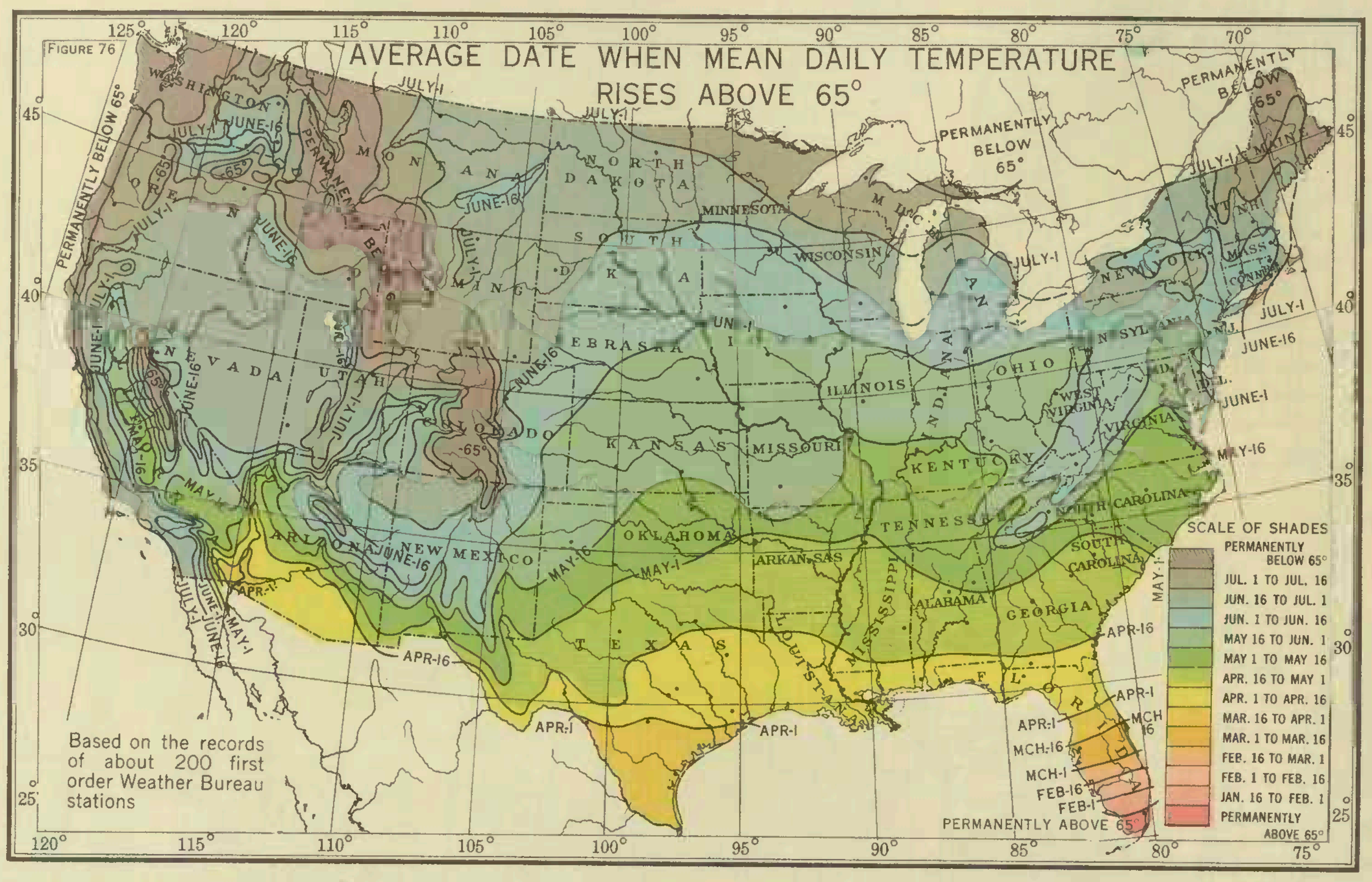


Figure 72. The graphs comprising this figure show for selected representative Weather Bureau stations and for each month of the year (1) the average monthly temperature, indicated by the solid, central line in the graph for each station; (2) the average daily maximum and the average daily minimum temperatures, indicated respectively by the upper and the lower dotted lines; (3) the average monthly maximum and minimum temperatures, that is, the average of the highest and lowest temperatures occurring each month, indicated respectively by the upper and the lower dashed lines; and (4) the absolute monthly maximum and minimum temperatures or the highest and the lowest temperatures ever recorded in each month, indicated respectively by the extreme upper and lower dot and dash lines. The graphs also show (5) the average daily range in temperature for each month, this being represented by the vertical distance between the dotted lines showing the average of the daily maxima and the average of the daily minima; (6) the average monthly range represented by the vertical distances each month between the dashed lines of average monthly maximum and minimum temperature; (7) the range in absolute monthly temperatures represented by the distances each month between the extreme dot and dash lines showing absolute maximum and minimum temperatures; and (8) the distance between the highest point reached by the top line and lowest reached by the bottom line shows the absolute annual range. The graphs are arranged geographically, each being placed directly over the location of the station it represents, the station in most cases being near the center of the graph. These graphs show the annual march of temperature and afford comparisons of important temperature data for the different sections of the country. The large diurnal monthly, and annual ranges in temperature characteristic of continental climates and the small ranges in temperature typical of marine climates will be noted upon comparing the graphs for the interior sections of the United States with those for the Pacific coast. The smaller annual range in temperature in the southern United States will also be noted upon comparing the graphs for the southern portion with those for the northern portion of the country

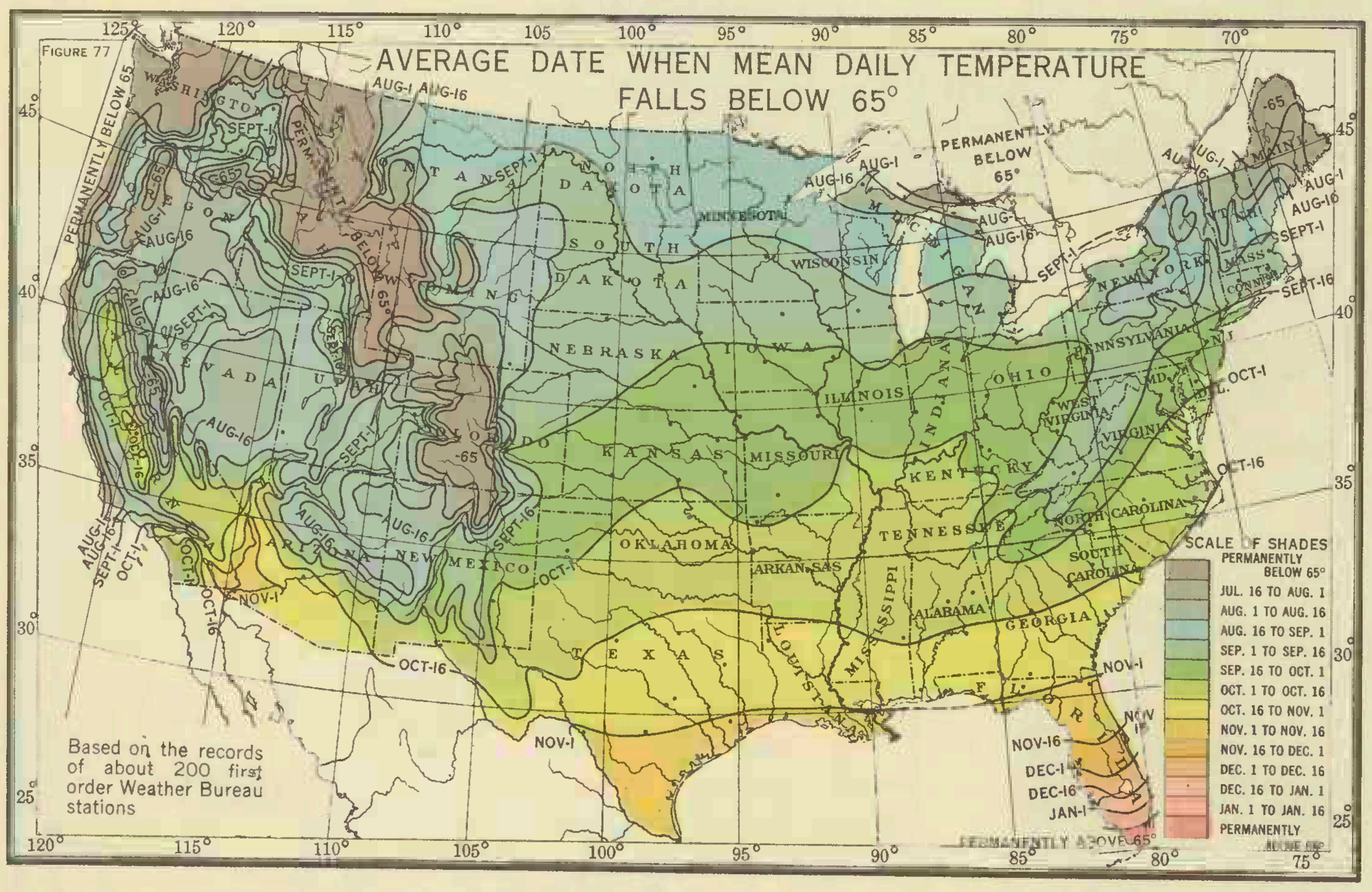


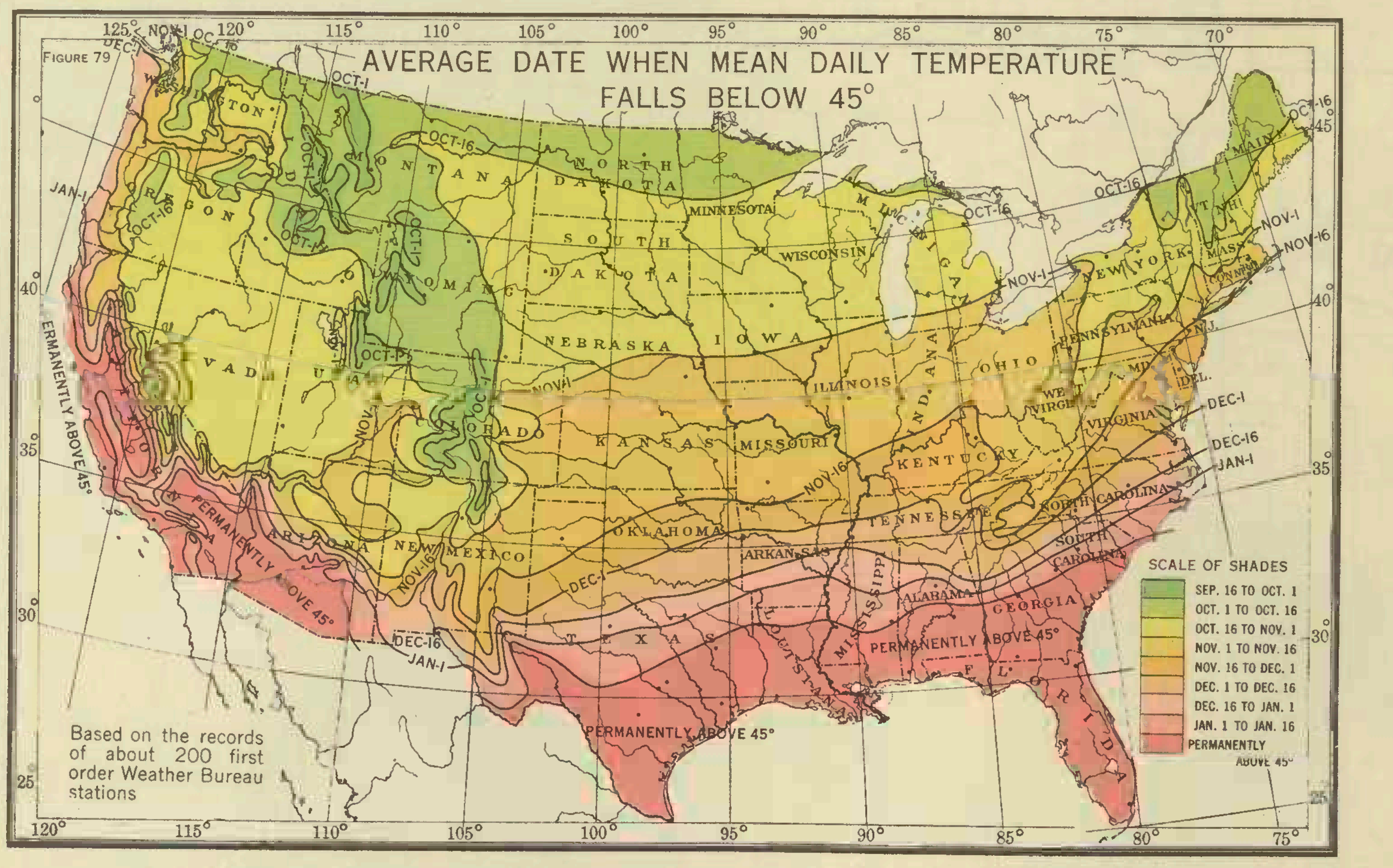


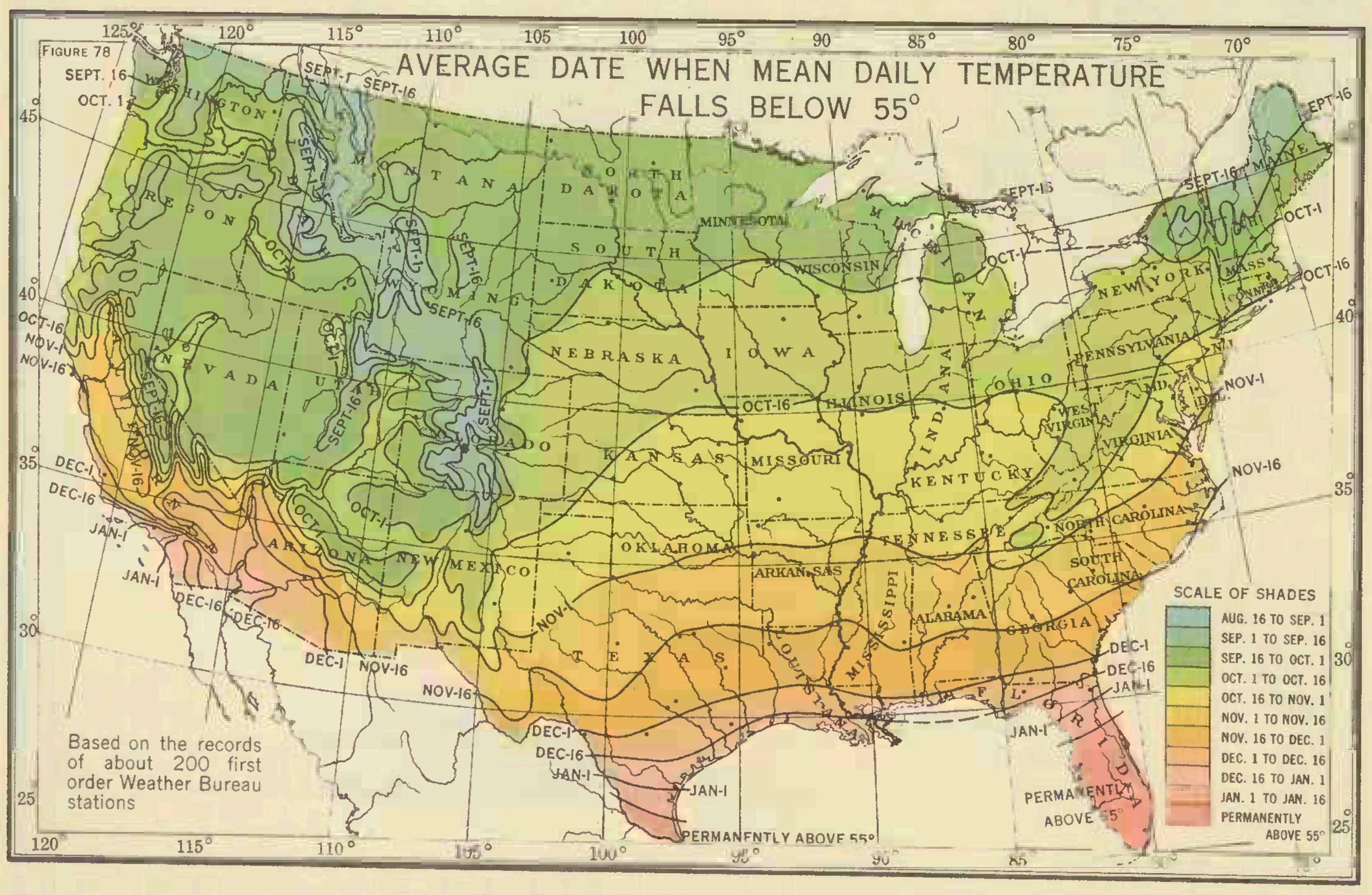


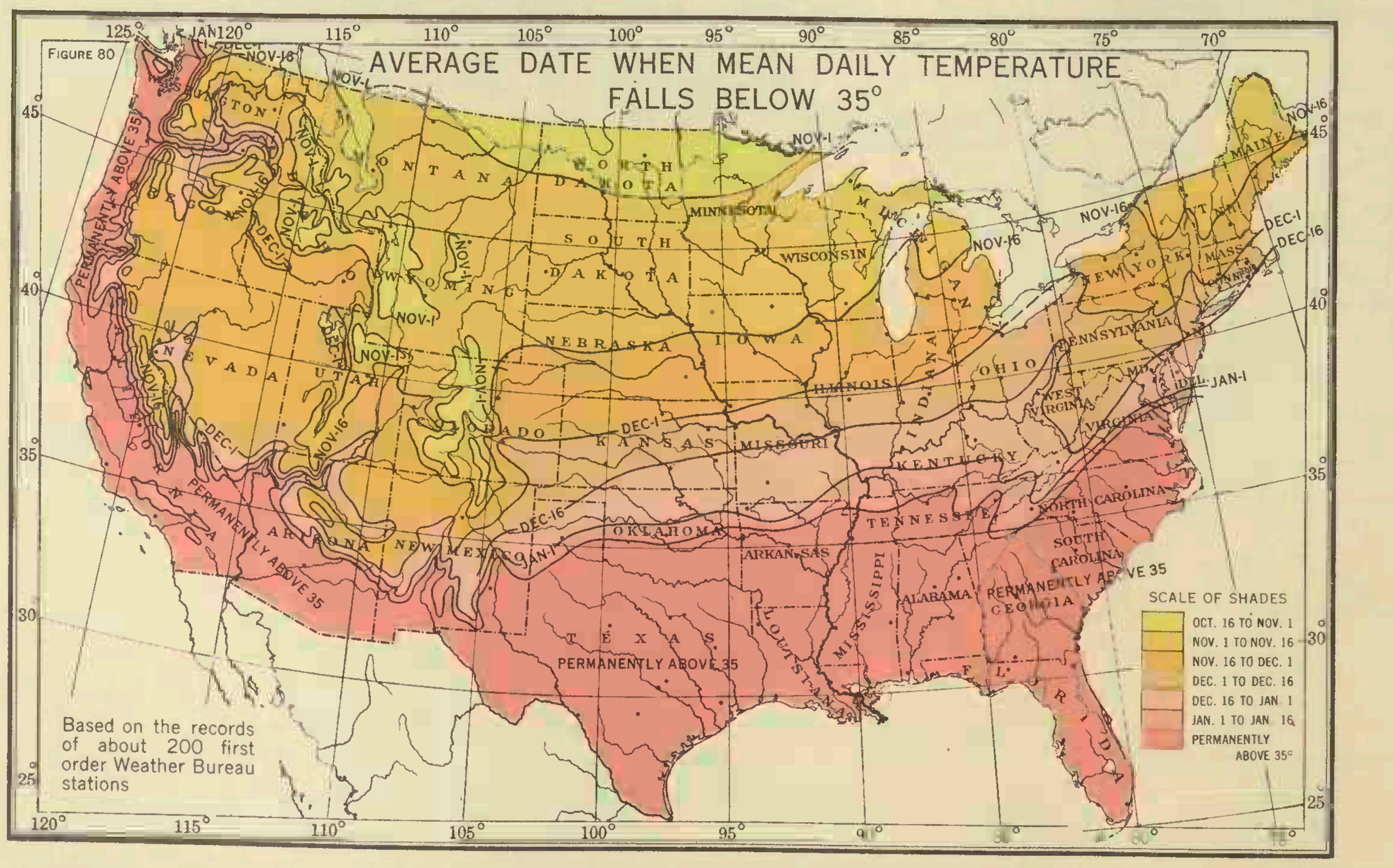


Figures 73, 74, 75, and 76 show the dates on which the average daily temperature in spring rises above 35°, 45°, 55°, and 65° F., respectively. These charts show the progress of the season as indicated by the movement northward of significant isotherms. The hardier cereals germinate and begin growth when the average daily temperature reaches about 35°; consequently the seeding of spring wheat begins in the Spring Wheat Belt about this time, followed by spring oats one or two weeks later. When the average temperature reaches about 45° potato planting begins throughout the Central and Northern States, and when 55° is reached the planting of corn has begun in the eastern United States. By the time 65° is reached corn planting is practically over in the Corn Belt and alfalfa is almost ready for the first cutting. This line of 65° reaches the eastern coast of Maine, the extreme upper Lake region, and the central and northern Rocky Mountain districts about July 20 and then immediately begins its retreat southward. In the regions to the north of or above this extreme limit of 65°, and along the immediate Pacific coast as far south as Point Conception, where also an average temperature of 65° is not attained during the summer, the crops are practically confined to hay, pasture, small grain, potatoes, and the hardier fruits and vegetables. In extreme southern Florida the average daily temperature never falls below 65°, and here limes, pineapples, and subtropical fruits are the important crops

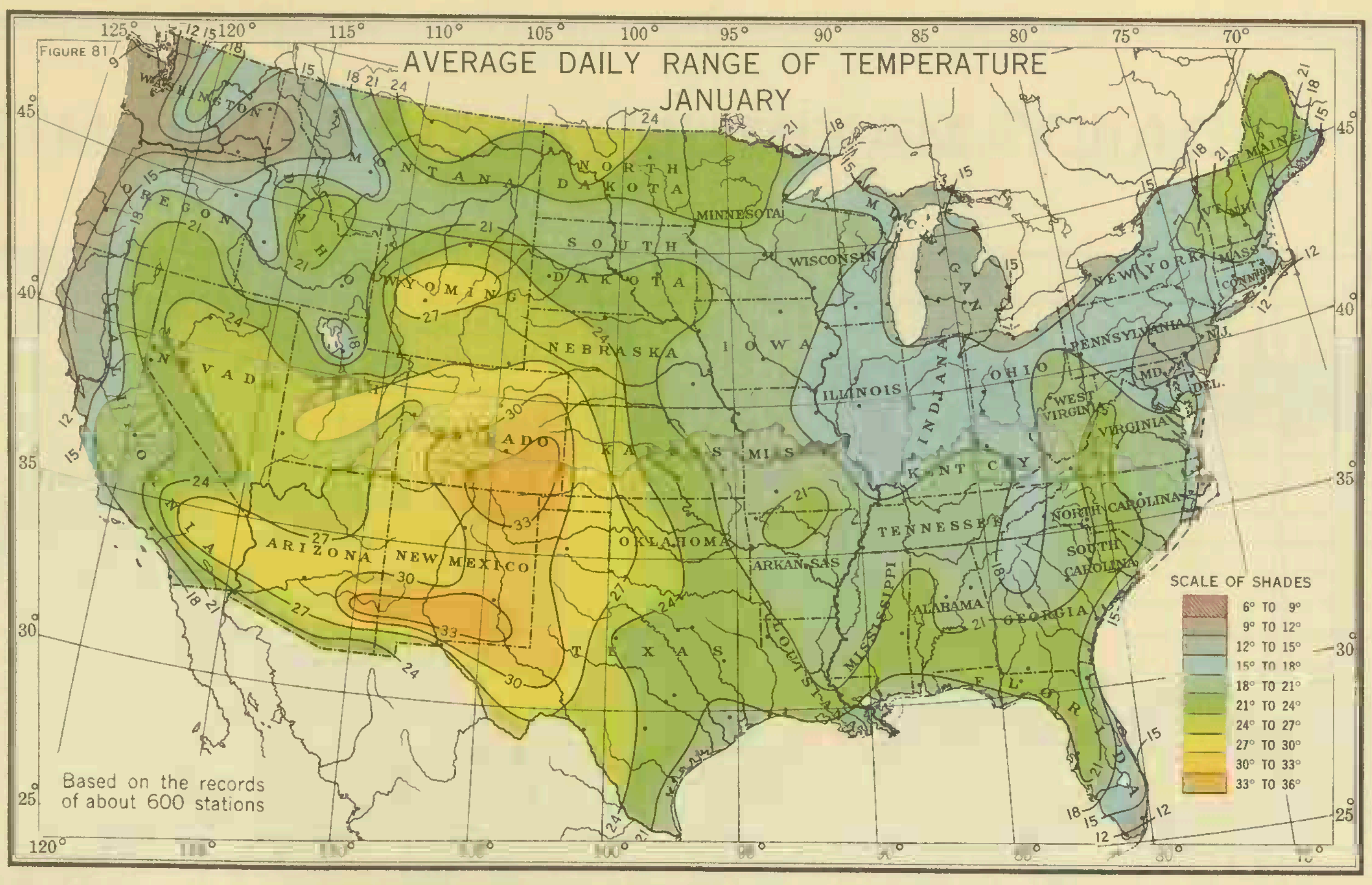


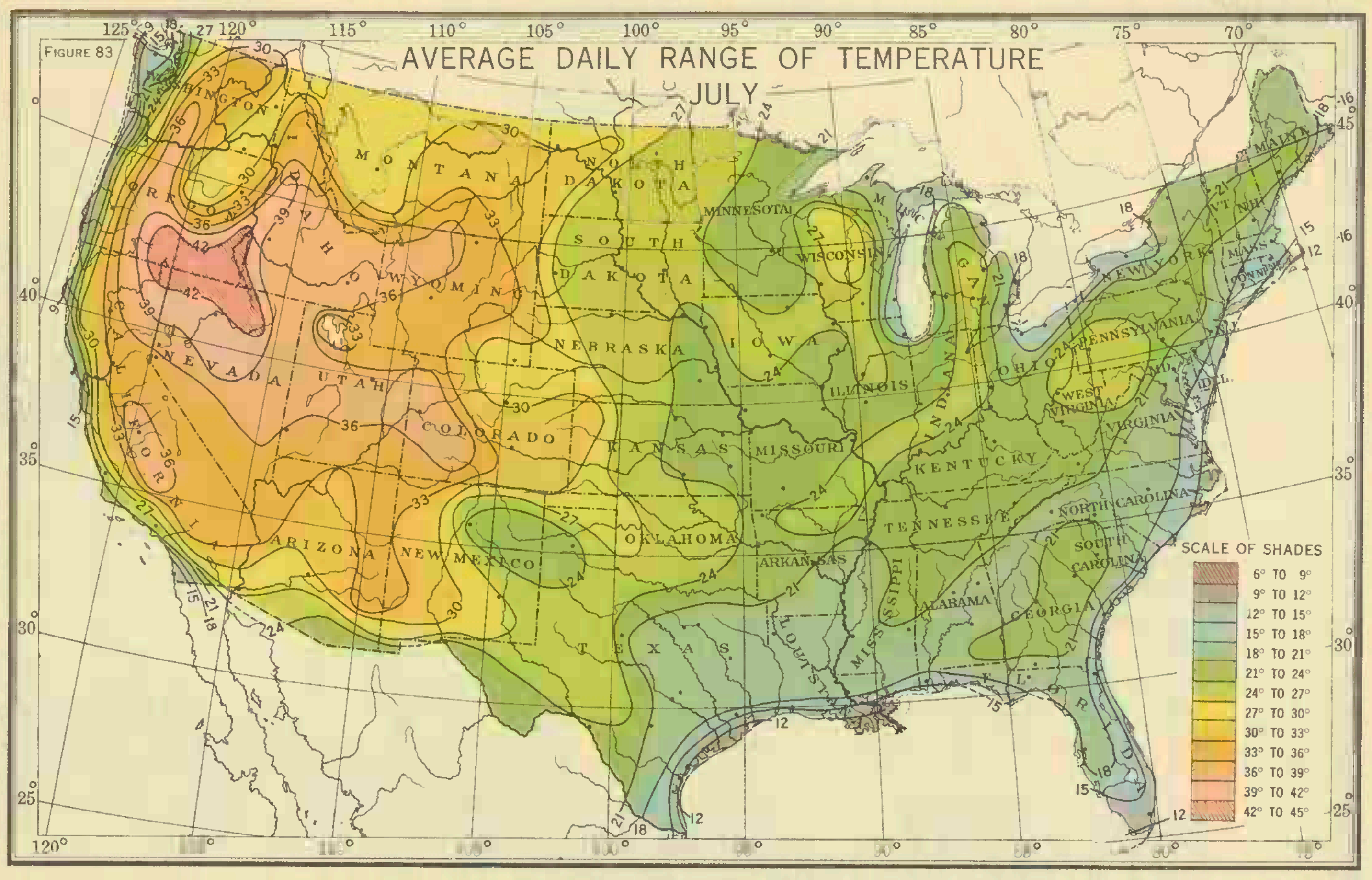


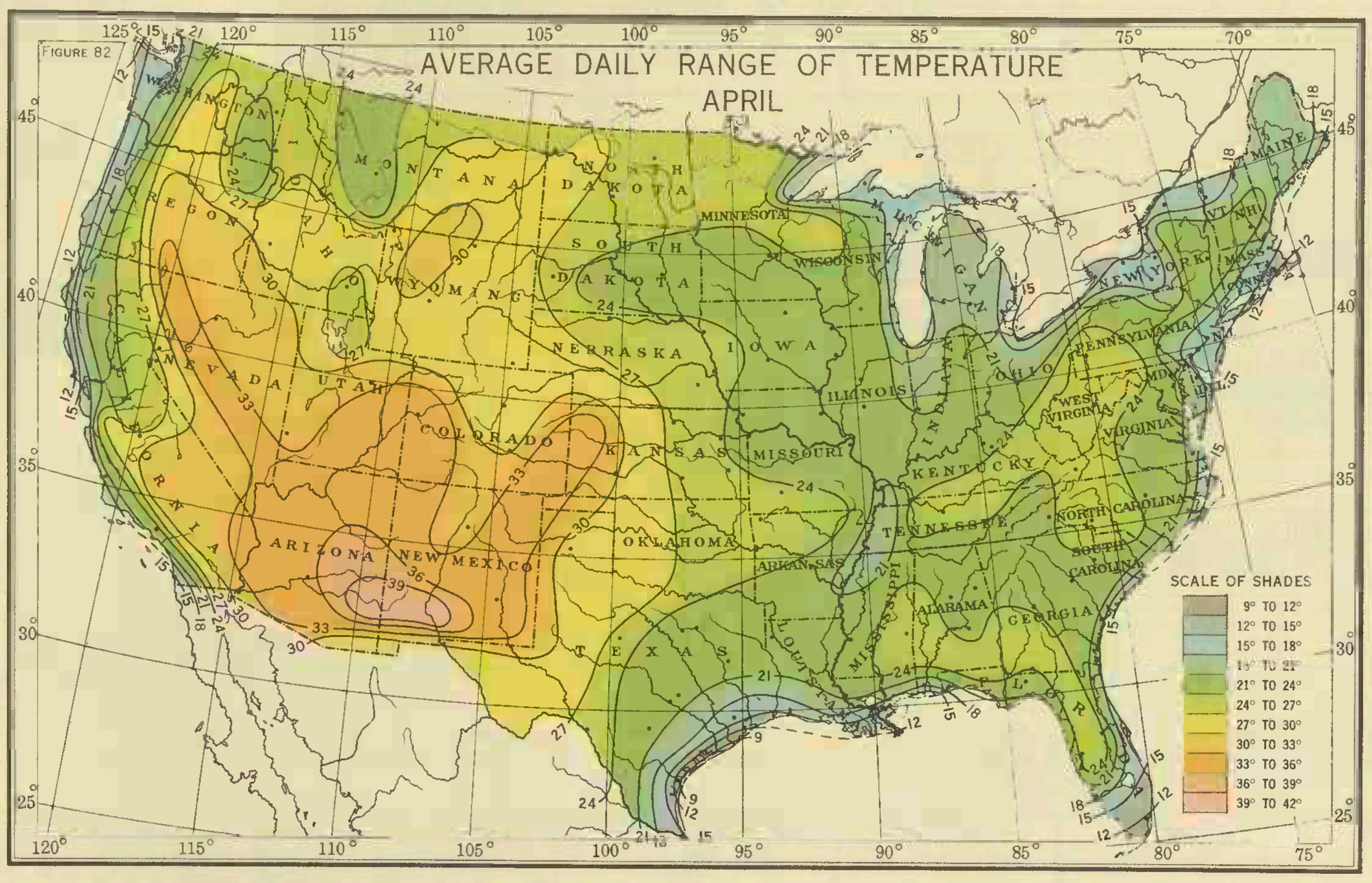


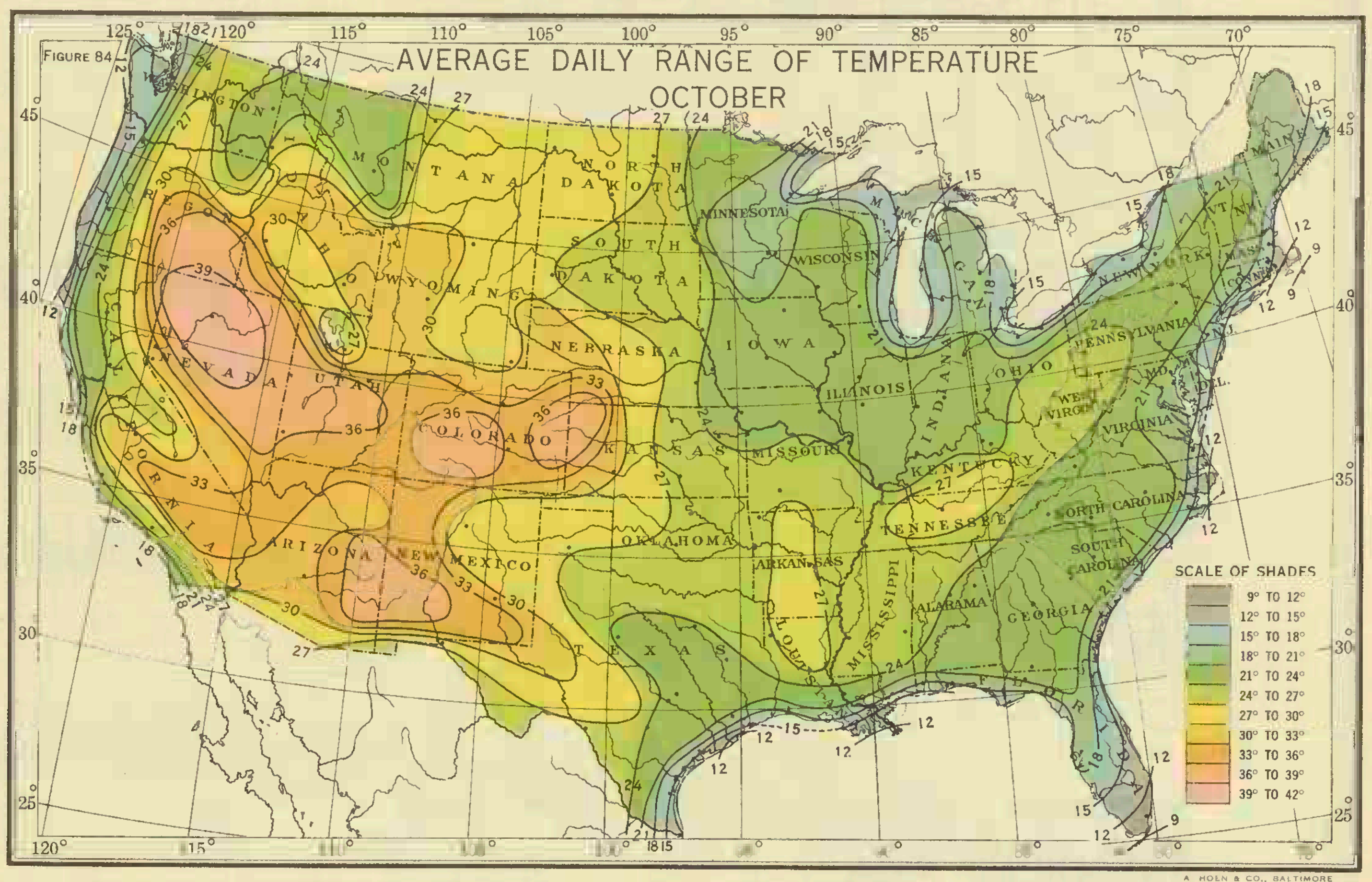


Figures 77, 78, 79, and 80 show the dates on which the average daily temperature in autumn falls below 65°, 55°, 45°, and 35° F., respectively. When the average daily temperature in the fall declines to 65°, the seeding of winter wheat becomes general throughout practically the entire Winter Wheat Belt; when it falls to 55°, the cutting and shocking of corn is in progress in the northern border States and husking or snapping from the standing stalk is beginning in the Corn Belt; when it falls to 45°, corn harvest is still in progress in the Corn Belt, but in the Cotton Belt cotton picking is nearly over. When the average daily temperature falls to 35°, corn harvest is practically over, and the first snow usually has fallen. In most of the Florida Peninsula and in extreme southern Texas the average daily temperature remains throughout the year above 55°; in southern South Carolina and in the Gulf States south of latitude 33°, in southwestern Arizona, and along the California coast as far north as Eureka it remains about 45°, and throughout nearly all the Cotton Belt, in southern New Mexico and Arizona, in the valleys of California, and along the Pacific coast it remains above 35°









Figures 81, 82, 83, and 84 show the average daily range in temperature for the months of January, April, July, and October, respectively. They represent the difference between the average of the maxima and the average of the minima temperatures of each day of the month. In January the least daily range is in the Puget Sound region, where it is less than 9° F., and the greatest daily range is in southern New Mexico and Arizona, where it is over 33°; in April the least daily range, 9° to 12°, is along the western Gulf, southern Florida, northern California, and southern Massachusetts coasts, and the greatest daily range, over 39°, is again in southern New Mexico and Arizona; in July the least daily range is along the north Pacific coast, and the greatest, over 42°, is in southern Oregon and northern Nevada; and in October the least daily range is in southern Florida and along the north Atlantic and north Pacific coasts, and the greatest is in northern Nevada. The equalizing influence of large bodies of water is everywhere evident, especially in July, and conversely the large daily range in temperature in arid climates is very apparent. In general the daily range in the interior of the country east of the Rocky Mountains ranges mostly between 20° and 30°, except around the Great Lakes, being smallest in winter and largest in late summer and fall, when the weather is driest

or the highest and the lowest temperatures ever recorded in the respective months.

Seasonal temperatures.—Of these the most important are the average summer and average winter temperatures. The average summer temperature is especially significant because in the more northern portions of the United States and at higher altitudes in the West the three summer months coincide more or less with the growing season of potatoes and of corn, whereas the average winter temperature shows many interesting correlations with the northern limits of winter wheat and several tree fruits. Figure 2 shows the average summer and Figure 5 the average winter temperature.

Average annual temperature.—The true average annual temperature is the average of the 365 successive average daily temperatures (24-hourly observations), but it is customary to compute it from the 12 monthly averages, based on the mean of the daily maximum and minimum. The difference between the results obtained by these two methods, due principally to the inequalities in the lengths of the months, is negligible, amounting generally to a very small fraction of a degree only.

The average annual temperature has relatively little value as an index to the actual temperature conditions in any locality, because of the great difference in seasonal variations in different sections of the country. For example, the mean annual temperatures at San Francisco, Calif., and at Wichita, Kans., having practically the same latitude, are nearly the same—about 55° F. The average daily minimum temperature at Wichita, however, for the three winter months is 24° as compared with 46° at San Francisco, and the average daily maximum for the three summer months at the former is 88° and only 65° at the latter. The average January temperature at San Francisco is 50° and at Wichita 30°, whereas the average July temperature is 57° at San Francisco and 79° at Wichita. There is obviously little similarity in the general temperature conditions at these two points, yet their annual averages are the same. For these reasons no chart showing the average annual temperature is included in the Atlas.

Average annual range.—The average annual range in temperature is defined as the difference between the average temperature of the coldest month and that of the warmest month. It affords an excellent expression of the rise in temperature that takes place from midwinter to midsummer. At Bismarck, N. Dak., the average

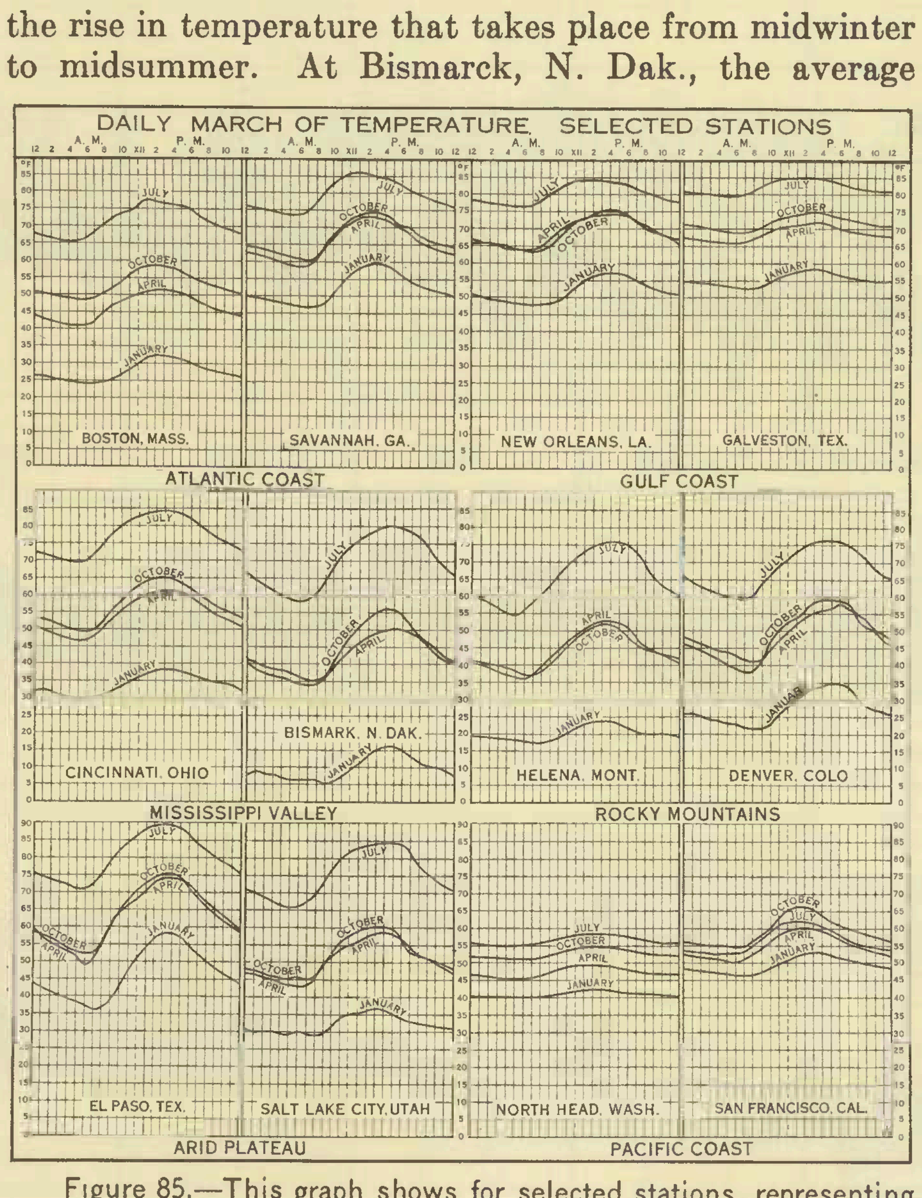


Figure 85.—This graph shows for selected stations, representing marine, continental, arid, and mountain types of climate, the average daily march of temperature. The amplitude of the daily march of temperature thus represented is considerably less than the average daily range in temperature, shown in Figures 81 to 84, particularly during the winter months, since the daily march represents the average temperature for each hour of the day, whereas the daily range is based on the daily extremes in temperature regardless of the hour of occurrence. The small daily variations in temperature in marine climates are shown by the graphs for San Francisco, North Head, Galveston, and to a less extent by that for New Orleans, the larger daily march in continental climates by the graphs for Cincinnati and Bismarck, and in mountain climates by the graphs for Helena and Santa Fe, and the still greater difference between day and night temperatures in arid climates by the graph for El Paso. The graph for Salt Lake City shows the marked influence of so small a body of water as Salt Lake in moderating the daily march of temperature

temperature of the coldest month, January, is 7° F. and that of the warmest month, July, is 70°, making an average annual range of 63°, whereas at San Francisco the average annual range is only 10°.

The greatest average annual range in temperature occurs in the northern interior districts of the United States and the least near the coasts, especially along the Pacific coast. In the Gulf and South Atlantic States it is about 30° F.; in the Middle Atlantic States, central Mississippi Valley, and the Rocky Mountain region it is from 40° to 50°, and from Montana eastward to the Lake region it is between 55° and 65°. The average annual range in temperature is shown graphically for different sections of the country in Figure 72.

ANNUAL MARCH OF TEMPERATURE

This is represented by the successive average daily temperatures. The change in the angle of inclination of the sun's rays and consequently in the length of the day is very slight for successive days and the resulting normal change in temperature from one day to another in the progress of the season is correspondingly small. In individual years the temperature fluctuations occasioned by the passage of cyclonic storms so disguise this gradual change that its occurrence can be realized only after the lapse of a number of days. (See fig. 86.)

As in the daily temperature march, there exists in the annual march of temperature, outside the equatorial region, a single maximum and a single minimum. In the United States the warmest month is July, except along the immediate Pacific coast where, because of the marine influence, it is often August or September, and the coldest month is January. The occurrence of these maximum and minimum temperatures is in general about a month later than the time when the sun reaches its highest and lowest altitude, respectively.

The progress of the seasons may be briefly summarized by months as follows:

January.—The average January temperature is shown for the different sections of the country in Figure 12. It varies greatly in different localities and the gradient from north to south is much steeper than in the warmer seasons of the year. The coldest weather occurs, as a rule, in the northern portions of Minnesota and North Dakota, where the average January temperature is near 0° F. Southward the temperature increases rapidly, the monthly average rising to the freezing point at approximately the latitude of the lower Ohio River, central Missouri, and southern Kansas, and to about 55° along

DAILY MAXIMUM AND MINIMUM TEMPERATURES AT SELECTED STATIONS

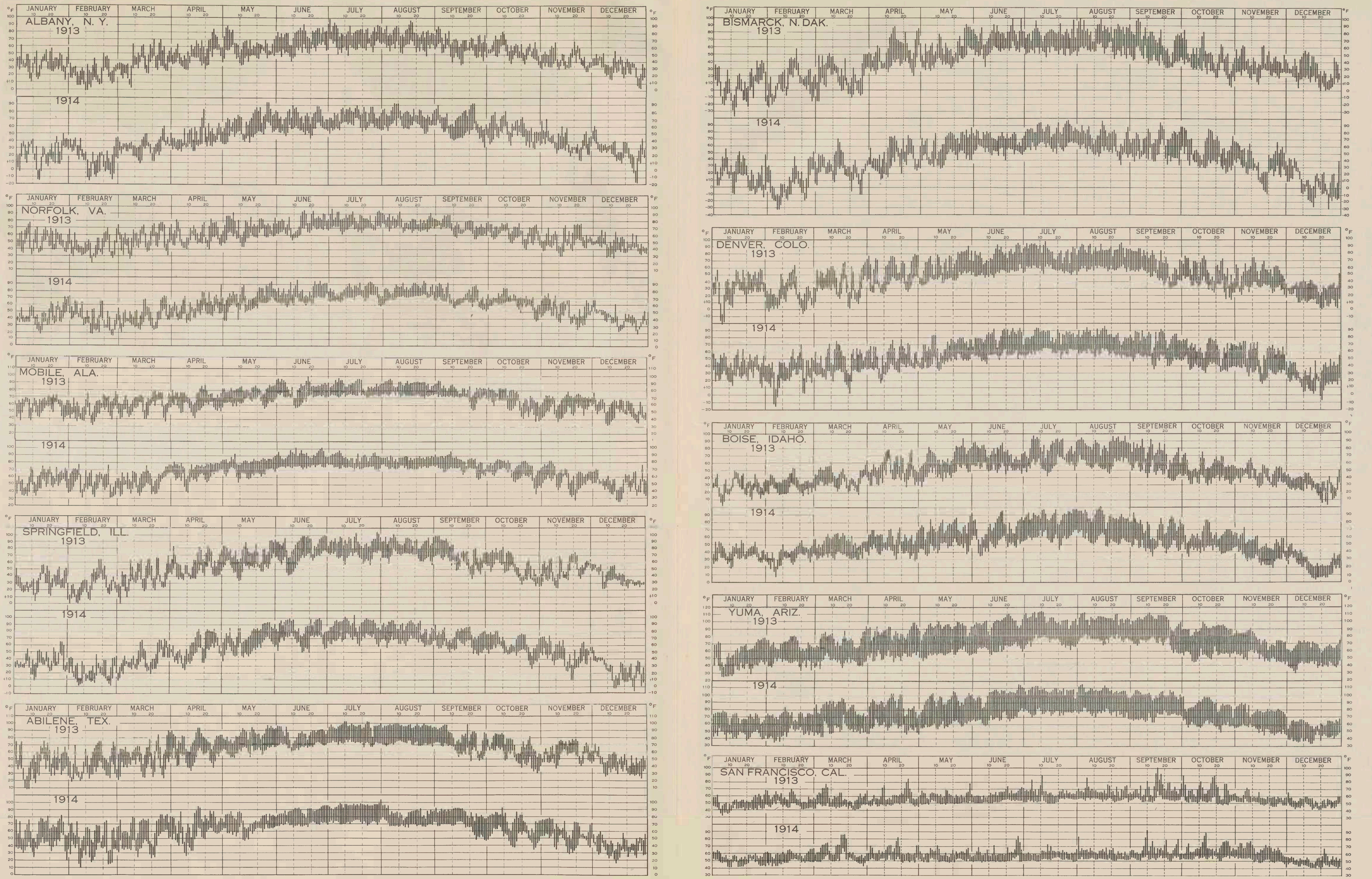


Figure [illegible].—This graph shows for selected stations, representing the principal types of climate in the United States, the daily maximum and the daily minimum temperatures for the years 1913 and 1914. In this graph the tops of the vertical bars show the daily maxima and the bottoms of the bars the daily minima. The lengths of the bars indicate the amplitude of the daily range, and the centers show the daily mean temperatures. The relative position of the bars for successive days indicates the daily variability. The graph shows the characteristics of temperature conditions for different sections of the country and for the several seasons of the year in a manner to facilitate comparison, and brings out important features not shown in maps or graphs based on average values. It visualizes, for instance, the abrupt temperature changes from day to day that may be expected to occur in the interior section of the country, especially during certain seasons of the year, and the more uniform conditions from day to day found in marine climates. For example, in the graph for Bismarck it will be noted that the maximum temperature rose above 60° F. for 11 successive days in mid-April, 1913, reaching 87° on the 14th and 89° on the 15th, and then on the 25th the minimum temperature fell to 24° and on the 26th to 20°. Such a long spell of warm weather would cause the blossoming of almost all kinds of fruit, and the cold wave following would kill the blossoms and forming fruit. A similar spell of warm followed by cold weather may be noted in April, 1914. Such wide fluctuations in temperature in the spring are characteristic of the climate of the Spring Wheat Belt; consequently very little fruit is grown in the region. At Bismarck changes in temperature of 30° in one day frequently occur, and on March 3, 1913, a rise in temperature from −15° to nearly 50° occurred. The graph for San Francisco affords a striking contrast to that for Bismarck. Changes in temperature of 30° in one day are rare, and the average daily range is only 12°. There is also very little difference in temperature between summer and winter; in fact, the difference between the average January and the average July temperature is only 9°. In 1914 the minimum temperature at San Francisco did not fall below 40° during the year, and the maximum rose above 70° on only 47 days. The continuous high summer temperatures in the far Southwest are shown by the graph for Yuma, Ariz. It will be seen that in 1914 the daily maximum temperature in that locality was 100°, or higher, on each day from June 10 to August 29, except for 1 day, a period of practically 80 consecutive days

the Gulf coast. From the Rocky Mountains westward to the Sierra Nevada and Cascade Ranges temperature conditions are determined largely by altitude, rather than by latitude as in the East. At the lower altitudes the average January temperature ranges generally from 20° to 35°, but is higher in portions of Arizona and New Mexico. High temperatures for the latitudes obtain along the Pacific coast, the January average ranging from about 40° on the extreme north coast to about 55° in southern California.

Throughout the interior of the continent January is characterized by frequent and abrupt temperature changes, resulting from the passage of cyclonic storms and accompanying anticyclones. The difference in temperature at the front and at the rear of a pronounced cyclone may be as great as 60° F. or more, and with rapid forward movement of the storm the temperature at a given place may fall 40° or 50° within a few hours. During this month very low temperatures are sometimes experienced in the northern interior portions of the country. In Minnesota, the Dakotas, and Montana temperatures of −40° to −50°, or lower, have been recorded in January and from −25° to −35° have occurred in the interior portions of New York and New England. The lowest temperature ever recorded at a Weather Bureau station in the United States was −65° in the eastern Montana in January, 1888. Along the central and southern California coast the lowest temperatures on record range from 27° to 29° and along the Gulf of Mexico coast from 11° to 15°. Freezing temperatures are of infrequent occurrence along the coast of southern California and likewise in extreme southern Florida.

February.—Figure 17 shows the average February temperature. This differs only slightly, as a rule, from that of January, February usually being slightly warmer. The lowest average temperature for this month, about 5° F., is found in the northern portions of Minnesota and North Dakota, whereas to the eastward over the upper Lake region and the northern portions of New York and New England the average February temperature is about 15°. To the southward there is a progressive increase to about 32° in central New Jersey, southern Ohio, central Missouri, and Kansas and to about 55° along the Gulf coast.

As in January, cold waves frequently sweep down from the Canadian Northwest during February and overspread all districts east of the Rocky Mountains, sometimes bringing extremely cold weather. In fact, the coldest weather of the year east of the Rocky Mountains occurs frequently during the early part of this month. A memorable cold wave occurred in February, 1899, which carried the line of zero temperature to the east-central Gulf coast and a temperature of 10° F. was recorded at Jacksonville, Fla. The coldest February temperature of record at a first-order Weather Bureau station in the United States is −55°, occurring in Montana in 1887. Temperatures as low as −25° have occurred in this month as far south as Kansas and Missouri. Toward the latter part of the month, however, the increase in temperature usually becomes noticeable, and along the immediate Gulf coast freezing weather does not occur, as a rule, after February 20.

March.—Figure 22 shows the average March temperature. With the advent of spring there is usually a rapid warming up in nearly all portions of the United States, although in the Pacific Coast States the increase in temperature is not pronounced, especially along the immediate coast. In the northern interior districts the increase in average temperature from February to March is about 15° F., but it diminishes to the southward, being only about half as great near the Gulf of Mexico. The average temperature for March on the northern border between Montana and Lake Superior is about 20°; along the Gulf coast it ranges from 60° to 65°.

In the northern States extremely cold weather occasionally occurs during March, temperatures of −35° to −40° F. having been recorded in this month in portions of North Dakota and eastern Montana. The March cold waves, however, usually lose intensity rapidly, and the Central and Southern States seldom experience severely cold weather in this month. Temperatures below zero have never been recorded in March south of the fortieth parallel, except in the Texas panhandle, Kansas, and a few localities to the eastward. In the Gulf States after March 15 freezing temperatures do not occur, as a rule, except in the extreme northern portions.

April.—Figure 27 shows the average temperature for April. As spring advances the increase in temperature becomes more rapid and consequently the warming up during April is greater than during March. Along the northern interior border of the United States the average temperature for April is about 20° F. higher than for March, but with progress southward the increase becomes less pronounced, amounting to about 10° along the Gulf coast. The average April temperature ranges from about 40° in the extreme North to about 70° at the Gulf. Along the immediate Pacific coast there is little change in temperature from the preceding month.

Cold periods prevail occasionally during April, especially in the more northern districts. The lowest temperatures on record for this month are slightly less than −10° F. near the Canadian border in North Dakota, and freezing temperatures have occurred early in the month as far south as Mobile, Ala., and northern Florida. Cold waves, however, are not of frequent occurrence during April and are of comparatively short duration. As a rule, freezing temperature is not experienced after April 15 south of a line extending from central Virginia, through western North Carolina, and the southern portions of Kentucky, westward to Missouri and Kansas.

May.—This month is characterized by the prevalence of mild temperatures, as shown in Figure 32. The average temperature in May ranges from about 50° F. along the northern border of the country to 75° at the Gulf, being from 7° to 10° higher than for April. Along the immediate Pacific coast the average temperature ranges from 50° at the extreme north to 60° in southern California. The highest average temperature, slightly over 80°, is found in extreme southern Texas and in portions of the far Southwest.

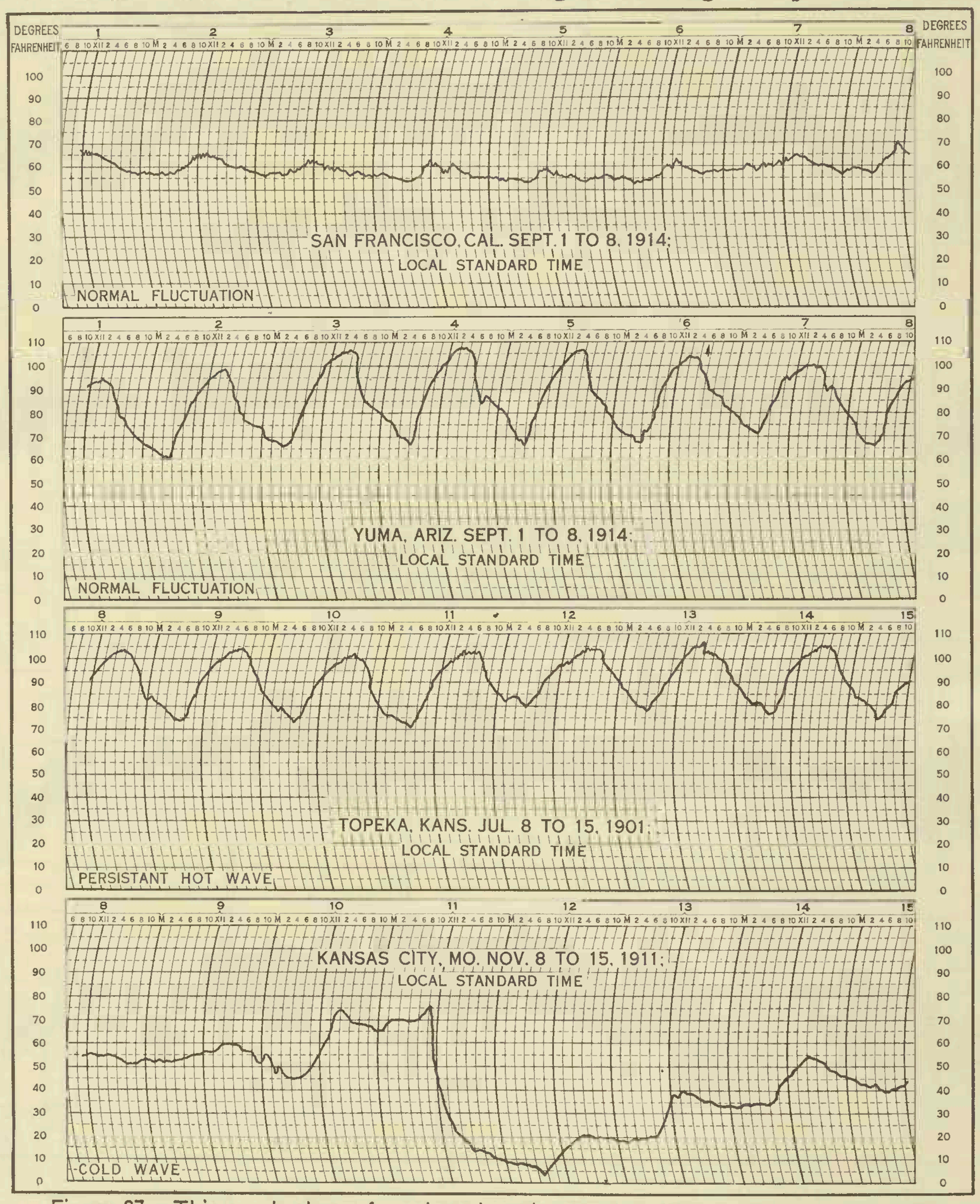


Figure 87.—This graph shows for selected stations and periods thermograph trace sheets, or continuous daily records of temperature. The trace sheets for San Francisco and Yuma are presented to contrast the daily march of temperature in the two extreme types of climate—marine and arid continental. In arid continental climates the fall in temperature is rapid after sundown and the rise pronounced during the morning hours, resulting in relatively cool nights and hot days. The marine type of climate, on the other hand, is characterized by comparatively uniform temperatures throughout the day. The trace sheet for Topeka, Kans., from July 8 to 14, 1901, was selected to show the temperature curve during a hot wave in midsummer, and that for Kansas City, Mo., from November 8 to November 14, 1911, to show the temperature curve during a severe cold wave in the late fall

The lowest temperature of record for May at a first-order Weather Bureau station is 6° F. in the northern portion of North Dakota. Freezing weather has been known to occur in this month as far south as northern Texas, and a temperature as low as 26° is on record in the panhandle of that State. East of the Mississippi River freezing temperature has never been experienced in May south of the Ohio River and southern Pennsylvania, except in some of the more elevated sections. As a rule, freezing temperature does not occur after May 10 south of South Dakota, the central portions of Iowa and Wisconsin, and the lower Lake region.

June.—Figure 37 shows the average June temperature. Along the northern border of the United States the average temperature for this month is about 60° F., or approximately 10° higher than for May. East of the Rocky Mountains there is a rather rapid increase in temperature from the northern border to about 70° at the latitude of central Iowa, and thence a less rapid rise to about 80° in the Gulf coast section. The average June temperature at the lower altitudes in most of the central and northern portion of the Rocky Mountain and interior Plateau regions ranges from about 60° to 70°, but in the extreme southern portion it is much higher. In the lower Colorado River Valley, in the extreme Southwest, the average June temperature is over 90°, whereas along the Pacific coast it ranges from 55° at the extreme north to 65° at the south.

High temperatures occur occasionally during June. The highest of record at a first-order Weather Bureau station is 117° F. at Yuma, Ariz., and records of 106° to 110°, have been made in the Plains States and in Montana. Temperatures of 100°, or higher, have occurred in June rather generally throughout the country, except in the Northeastern States, the vicinity of the Great Lakes, in the higher altitudes of the Rocky Mountain and interior Plateau regions, and along the north Pacific coast. The average date of the last freezing temperature in spring in the extreme northern portions of Minnesota and North Dakota is about June 1, but it is later than this in some of the elevated districts of the West.

July.—Figure 42 shows the average July temperature. This is, as a rule, the warmest month of the year, except in localities having the marine type of climate. East of the Rocky Mountains the average July temperature ranges from a little less than 70° F. in the northern border States to about 82° along the Gulf coast. The temperature gradient from north to south in the summer season is much smaller than in the winter. The difference between the average July temperature along the northern border of the United States east of the Rockies and that on the Gulf coast is about 15°, but for January it is about 50°. The highest July temperature in the United States is found usually in southwestern Arizona and the interior valleys of southern California, where the average for the month ranges from 90° to 98°. Along the Pacific coast the summers are cool, the average July temperature ranging from about 55° in western Washington to 67° in southwestern California.

In July periods of hot weather are comparatively frequent in most sections of the country, and very high temperatures are sometimes experienced. Occasionally the hot waves are of unusually long duration, particularly in the sections east of the Rocky Mountains, and at such times suffering, especially in the congested districts of the large cities, is intense. In some of the important agricultural districts, particularly in the Middle West, the heated periods are occasionally accompanied by "hot winds," which prove disastrous to growing crops. The highest temperature of record for July at a first-order Weather Bureau station is 118° F. at Yuma, Ariz., and in the Great Valley of California temperatures of 110° to 115° have occurred. A maximum temperature of 134° has been recorded at a cooperative station in Death Valley, Calif., which is the highest official temperature ever recorded in the United States and probably in the world. In the Plains States and Mississippi Valley temperatures of 105° to 110° have been experienced, and records of 100° or higher have been made generally throughout the country, except in some restricted areas. Although the average summer temperature in the Southern States is considerably higher than in the Northern, extremely hot weather occurs occasionally in practically all northern sections of the country. In fact, higher temperatures are on record in the Dakotas and Montana than have ever occurred in Mississippi, Alabama, or Florida.

August.—Figure 47 shows the average August temperature. This differs little from that for July, but as a rule August is slightly cooler, except on the Pacific coast. At some points on the Pacific coast September is the warmest month of the year. East of the Rocky Mountains the coolest August weather occurs in northern Michigan and in the interior of New York and New England, where the average temperature for the month ranges from about 62° to 65° F. At points in the far Southwest it is as high as 95° or more. The remarks as to July temperature conditions in general apply also to those of August.

September.—Figure 52 shows the average temperature for September. The average September temperature ranges from about 55° F. in the northern border States, where it is about 8° lower than for August, to about 78° along the Gulf coast, where it is 2° or 3° lower. At the lower elevations of the Rocky Mountain and interior Plateau regions it is mostly from 50° to 65°. In the Great Valley of California the average September temperature is 70° to 75°, and in southwestern Arizona it is 80° to 85°.

High temperatures sometimes occur in September, especially between the Rocky Mountains and Mississippi River. The highest of record for this month at a first-order Weather Bureau station in this region is 106° F., in eastern South Dakota, and temperatures of

100° or higher have been quite generally experienced. East of the Mississippi River only a few stations have temperature records for September as high as 100°. In portions of California high temperatures are reported occasionally in this month, the highest of record at a first-order station of the Weather Bureau being 111° at Fresno, Calif. Cool weather also occasionally obtains in September, freezing temperatures having occurred as far south as the southern portions of Kansas and Missouri and the Ohio River Valley. The average date of the first freezing temperature in fall in most of the Dakotas and Minnesota, in northern Wisconsin, and at the higher elevations of New York and New England ranges from September 15 to 30.

October.—Figure 57 shows the average temperature for October. During October there is a considerable decrease in temperature, except in extreme southern Florida and along the Pacific coast, the decrease being generally as much as 10° to 15° F. Along the extreme northern border of the country the average October temperature is about 45°, increasing with progress southward to about 70° along the Gulf coast. West of the Rocky Mountains at the lower altitudes the average for the month ranges from somewhat less than 40° to about 50°, except that it is higher in the far southwestern region. On the Pacific coast the average temperature ranges from 50° at the north to 60° at the south.

Temperatures below zero have been experienced at a few points in the north Central States in October, the lowest of record at a first-order station of the Weather Bureau being −16° F. in northern Montana, and freezing temperatures have occurred nearly to the Gulf coast. On the average freezing weather occurs by the last of October as far south as the northern portions of South Carolina, Georgia, Alabama, and Mississippi and the central portions of Arkansas, and Oklahoma.

November.—Figure 62 shows the average temperature for November. During November the decrease in temperature as a rule is rather pronounced, the average for the month being mostly from 10° to 15° F., or more, lower than for October, except along the Gulf and Pacific coasts. East of the Rocky Mountains the average November temperature ranges from about 25° in the north-central border States to somewhat more than 60° along the Gulf, but in southern Florida it is 70° or higher. Along the Pacific coast the average temperature is 45° at the north and about 60° at the south.

During November cold waves of considerable severity sometimes advance from Canadian Northwest and overspread the north Central States (see Kansas City thermograph record in Figure 87), but they usually lose energy rapidly in their eastward and southward progress and seldom are of long duration. Zero temperatures have never been recorded at a first-order Weather Bureau station in November south of the Ohio River, but freezing has occurred as far south as Tampa, Fla. The lowest temperature of record for this month is −33° in northern Montana.

December.—Figure 67 shows the average temperature for December. Temperatures, as a rule, continue to decrease rapidly during December. East of the Rocky Mountains the decrease in the monthly averages from November to December range from about 15° F., in the extreme northern portion of the country to 7° or 8° along the Gulf coast, but along the Pacific coast December is only 3° or 4° cooler than November. The average December temperature is about 10° in the north Central States, about 55° along the Gulf coast, and 70° in extreme southern Florida. In the lower altitudes of the Rocky Mountains and interior Plateau regions the average December temperature is mostly between 20° and 30°, except in New Mexico and Arizona, where it is locally as high as 55°. Along the Pacific coast it ranges from 44° to 56°.

During December cold waves usually become more frequent and severe, and very low temperatures are occasionally experienced in much of the interior portion of the country. The lowest temperature of record at a first-order Weather Bureau station for this month is −50° in northern Montana, while temperatures of −10° to −15° have been experienced as far south as the southern portions of Kansas and Missouri, and −5° in portions of Tennessee and North Carolina. The lowest recorded temperature along the Gulf coast in this month is 14°, occuring at Mobile, Ala., and also at Pensacola, Fla. Along the central and eastern Gulf coasts the average date of the first freezing temperature in fall is about December 1.

SIGNIFICANT TEMPERATURES

Figures 73 to 80 show the progress of the season with reference to certain significant temperatures. The averages dates in spring on which the daily mean temperatures rises above 35°, 45°, 55°, and 65°, F. in different portions of the country are shown by Figures 73 to 76, respectively, whereas Figures 77 to 80 show the average dates in fall when the daily means fall below these values.

Figures 3 and 6 show for the different sections of the United States the highest and lowest temperatures ever recorded, and Figure 4 shows for selected stations the highest temperatures recorded each year for the 20-year period—1895–1914.

Figure 7 shows the average of the lowest temperatures recorded each year, and Figures 8 and 9 show the number of times in the 20-year period—1895–1914—that the minimum temperature each year was 6° and 9° F., respectively, below this average minimum.

Figure 10 shows the average annual number of days on which the minimum temperature falls to freezing and Figure 11 the average annual number of days with temperature continuously below freezing for the entire day.

AVERAGE MONTHLY TEMPERATURES AT SELECTED STATIONS

[Monthly mean temperatures]

ALABAMA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Anniston	43.7	44.7	54.1	60.8	68.9	76.0	78.0	77.8	73.2	62.8	51.6	44.0	29
Birmingham	46.0	46.4	56.6	62.7	71.8	78.0	80.0	79.8	75.3	65.2	54.4	45.8	33
Decatur	41.8	42.8	53.2	61.6	69.9	77.5	79.8	78.7	73.1	61.6	50.5	42.5	39
Fort Deposit	47.2	48.7	58.1	64.9	73.3	79.4	81.2	80.2	76.1	65.5	55.3	47.4	37
Goodwater	44.6	44.9	55.8	62.1	71.2	77.8	79.7	79.4	75.2	64.0	53.6	44.5	26
Greensboro	46.0	48.4	56.2	63.6	71.6	78.6	80.1	79.5	75.3	64.7	55.1	48.1	39
Hamilton	43.0	43.5	54.0	60.5	69.5	76.0	79.0	79.7	74.9	62.9	52.1	44.0	22
Mobile	51.2	53.9	60.1	66.6	73.9	79.9	81.4	81.0	77.6	68.4	58.8	52.3	50
Montgomery	48.4	51.0	58.3	65.2	73.2	79.9	81.6	80.7	76.3	66.2	55.9	49.0	49
Opelika	46.0	47.5	56.6	63.6	71.9	78.5	80.1	79.1	74.6	64.1	54.5	46.2	39
Ozark	49.5	50.4	60.6	65.3	73.9	79.6	82.7	80.8	77.1	67.1	56.9	49.9	19
Scottsboro	41.9	42.4	52.5	60.1	68.1	75.1	77.9	77.2	71.9	61.0	50.2	42.4	36
Thomasville	47.6	49.1	58.3	64.4	72.7	79.4	80.8	80.4	76.0	65.0	55.4	48.1	29
Tuscaloosa	44.4	45.4	55.4	63.0	71.9	79.0	81.3	80.6	75.7	64.2	52.8	45.9	39
Tuscumbia	41.0	42.4	52.4	60.9	69.3	77.3	79.7	78.7	72.9	61.2	50.4	42.4	39

ARIZONA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Dudleyville	48.2	51.4	56.3	62.4	69.1	78.6	83.0	81.4	76.1	65.3	55.0	47.5	28
Flagstaff	27.8	30.4	36.1	43.2	50.0	59.3	65.2	63.7	56.6	46.4	37.0	28.6	27
Fort Apache	34.6	38.4	43.6	51.8	58.1	67.0	71.2	70.1	63.9	53.6	43.6	36.0	40
Fort Grant	45.1	48.0	52.5	58.8	66.9	76.0	78.7	75.7	72.3	63.4	54.0	47.0	24
Fort Huachuca	46.2	48.3	55.0	60.6	66.7	76.4	76.6	74.8	71.2	63.2	52.6	45.8	32
Fort Mohave	49.8	56.2	62.6	70.2	78.1	87.2	93.8	91.6	84.2	71.6	59.8	50.6	21
Gila Bend	53.9	56.5	63.2	68.0	75.2	86.3	92.0	91.0	85.2	72.9	62.0	52.1	22
Grand Canyon	28.5	32.0	36.2	43.7	49.4	61.6	76.6	65.4	57.0	47.9	38.6	29.6	15
Holbrook	33.1	39.7	45.7	52.6	60.4	70.2	75.6	74.7	67.2	63.8	43.2	34.2	24
Jerome	42.2	45.6	50.6	58.6	64.6	76.2	78.8	76.7	72.4	61.6	51.8	43.2	22
Parker	49.8	55.4	61.4	68.6	75.4	84.8	90.0	90.4	82.9	71.2	58.2	49.5	25
Phoenix	51.8	55.6	60.1	67.0	73.9	84.6	89.2	88.0	82.4	70.4	59.8	51.3	27
Salome	47.0	50.5	56.0	62.4	69.2	81.2	86.6	85.6	78.8	66.5	56.4	46.8	13
Tucson [1]	50.0	52.6	57.8	63.5	71.9	81.3	85.5	83.6	79.3	67.9	57.6	49.9	35
Yuma	54.4	58.6	64.1	69.5	76.2	84.7	90.8	90.4	83.7	73.3	62.4	55.2	40

ARKANSAS

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Bee Branch	41.3	42.1	52.6	60.9	68.6	76.8	80.0	79.4	74.4	62.6	51.3	42.2	29
Brinkley	41.8	43.0	52.4	60.7	70.0	77.7	80.8	80.2	74.6	62.1	51.8	43.4	35
Camden	44.9	47.0	56.0	63.7	71.2	78.2	81.0	80.2	75.4	63.7	52.2	45.1	31
Dodd City	37.6	37.8	47.6	58.7	66.9	74.6	78.1	77.5	71.8	60.0	48.9	39.2	28
Fayetteville	38.0	39.3	49.9	58.0	66.2	74.2	78.0	77.6	72.4	60.9	49.8	39.9	31
Fort Smith	39.5	42.8	51.3	61.7	69.7	78.0	81.0	79.4	72.7	61.7	49.9	41.7	41
Helena	43.0	43.6	53.8	62.4	70.8	78.2	81.3	80.6	74.8	62.5	53.2	44.8	30
Hot Springs	43.2	46.8	53.9	62.9	69.8	77.6	81.3	80.0	75.2	64.0	52.7	44.6	25
Jonesboro	40.4	41.5	52.8	61.2	69.8	77.6	79.9	79.9	74.3	62.5	51.4	41.0	26
Junction	45.6	47.1	57.2	65.6	71.8	79.4	81.9	80.8	75.6	64.2	53.9	46.1	28
Little Rock	41.8	44.2	53.6	62.4	70.0	77.6	80.8	79.7	74.2	63.5	52.3	44.0	43
Mena	41.3	43.6	52.6	61.4	68.9	76.4	79.8	79.4	73.8	62.8	53.1	42.6	30
Newport	39.2	40.5	52.6	61.8	70.0	77.8	81.0	79.8	73.8	61.4	51.0	41.9	34
Pine Bluff	43.1	45.4	54.8	64.4	72.0	79.0	82.2	81.4	73.1	62.6	52.8	44.4	34
Pocahontas	38.0	40.4	51.6	60.0	68.6	78.0	81.7	81.0	74.8	62.9	51.2	40.8	28
Portland	46.3	48.5	58.8	63.7	71.3	79.2	81.5	81.1	76.4	64.8	53.9	47.4	16
Texarkana	46.2	47.8	56.8	63.8	71.6	79.0	82.3	81.9	76.8	64.6	55.4	46.8	36

CALIFORNIA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Bagdad	52.8	57.1	63.8	72.8	79.1	89.1	95.2	93.8	84.2	65.9	61.1	52.5	17
Bakersfield	47.4	52.2	56.3	62.6	69.7	77.8	84.0	81.8	74.1	65.4	55.7	47.9	34
Barstow	46.3	50.4	56.4	61.8	67.4	77.8	83.6	82.4	74.2	64.0	54.2	45.9	17
Bishop	37.0	41.6	46.2	52.9	59.0	66.9	72.8	71.4	63.9	55.0	45.6	38.0	22
Branscomb	42.6	44.2	45.9	49.8	53.4	59.2	66.4	66.1	61.9	57.0	49.0	43.6	18
Cedarville	29.7	33.0	38.6	46.5	52.6	61.4	70.3	69.0	60.0	49.6	39.5	30.6	27
Colusa	45.6	49.4	53.5	58.2	64.7	71.8	76.8	75.2	69.7	61.8	52.3	44.9	20
Crescent City	46.2	47.0	48.0	50.0	52.2	55.7	57.8	58.1	57.8	54.9	50.5	46.6	22
Escondido	50.0	52.1	55.1	58.5	62.5	68.4	72.5	72.4	68.9	62.3	56.1	50.4	26
Eureka	46.8	47.1	48.2	49.8	52.0	54.4	55.6	56.2	55.6	53.5	51.0	47.8	37
Fresno	46.2	51.1	54.8	60.5	66.6	75.2	81.9	80.5	73.5	64.4	54.5	46.4	35
Georgetown	42.4	44.4	47.1	52.6	56.6	66.1	74.4	73.6	67.5	58.9	50.1	44.5	20
Greenland Ranch	52.9	58.2	65.5	75.3	82.6	94.5	101.2	99.0	89.7	74.8	60.9	52.1	9
Hollister	48.1	51.2	53.6	56.8	60.2	64.4	66.1	65.8	65.0	60.4	53.9	48.9	49
Indio	53.4	58.7	65.0	72.4	79.0	88.0	93.6	92.4	85.9	75.2	62.8	55.5	42
King City	49.1	50.7	54.2	57.5	61.2	65.1	68.2	68.7	67.7	61.8	55.4	50.5	35
Lodi	46.2	50.1	54.7	58.3	63.4	69.1	73.7	73.0	69.7	62.3	53.6	47.3	30
Los Angeles	54.5	55.5	57.3	59.7	62.1	65.2	70.2	71.1	69.4	65.1	60.9	55.3	42
McCloud	34.0	36.6	40.4	45.8	51.9	59.0	63.9	64.0	57.4	50.0	42.2	35.0	13
Merced	46.3	49.5	53.2	59.4	66.1	74.4	80.6	78.8	72.7	63.6	54.0	47.2	49
Mojave	46.0	49.0	52.2	59.5	68.0	77.4	85.5	83.7	76.3	65.7	54.6	47.2	37
Napa	46.8	50.1	52.2	55.8	59.2	64.9	66.8	66.2	65.6	61.0	53.4	47.8	25
Orleans	44.8	48.4	53.6	59.0	62.8	67.5	76.3	75.8	69.0	60.4	51.4	45.0	18
Red Bluff	45.4	49.5	53.8	59.3	66.2	74.8	81.3	80.0	73.2	63.6	54.0	46.2	46
Redlands	50.9	52.7	55.8	60.1	63.6	71.4	76.8	76.6	72.2	65.4	58.2	52.2	27
Sacramento	45.2	49.8	53.5	58.1	63.3	70.2	73.9	73.3	70.3	62.7	53.3	46.5	46
San Diego	54.3	55.0	56.9	59.2	61.3	64.8	68.1	69.7	67.9	63.9	59.5	55.7	68
San Francisco	50.0	52.3	53.6	55.2	56.5	58.5	58.5	59.0	61.2	60.3	56.3	51.2	52
San Luis Obispo	51.9	53.5	54.6	56.2	57.4	61.9	64.2	64.7	64.4	62.1	57.5	53.0	28
Santa Barbara	53.4	54.4	55.6	57.7	59.1	62.3	65.5	66.7	65.7	62.7	58.8	55.1	38
Sterling	54.2	55.8	56.4	57.5	59.9	62.1	66.2	67.4	66.1	62.0	58.6	54.8	18
Susanville	30.3	34.6	40.4	47.0	52.7	61.2	68.2	67.4	59.0	49.9	40.4	31.6	20
Ukiah	44.5	47.8	50.5	55.1	59.2	66.5	71.7	70.9	65.9	60.0	50.2	44.3	27
Yosemite	32.6	38.4	43.6	50.6	54.7	63.0	69.4	68.4	62.0	53.3	41.6	33.8	16

COLORADO

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Breckenridge	15.4	15.6	22.4	30.0	39.0	48.6	53.4	53.0	46.6	35.9	25.6	15.2	22
Burlington	27.8	31.4	40.2	47.6	57.5	68.4	73.6	72.5	64.8	52.0	40.6	29.0	18
Canon City	35.3	35.2	42.9	50.0	57.4	66.1	72.9	72.3	64.3	53.1	43.4	35.9	29
Cheyenne Wells	28.0	30.0	39.4	48.6	58.1	68.4	73.7	72.8	64.8	52.4	39.5	28.0	26
Colorado Springs	30.0	29.6	37.5	44.6	53.1	62.0	67.0	66.2	59.6	48.8	38.7	30.6	29
Delta	24.5	31.6	41.8	50.5	59.0	68.0	74.0	71.5	62.6	50.4	38.8	25.6	28
Denver	30.2	32.2	39.2	47.2	56.4	66.6	72.0	70.9	62.6	51.2	39.7	32.2	51
Durango	25.5	30.0	37.6	45.2	52.7	61.4	67.2	66.2	58.9	48.1	38.6	26.9	28
Fort Collins	26.2	27.4	36.0	44.8	53.8	63.1	68.0	67.5	59.2	48.0	36.1	27.2	28
Grand Junction	25.5	32.8	43.5	52.2	61.0	71.6	77.4	75.4	66.4	53.1	40.2	27.6	31
Greeley	26.0	27.8	38.0	47.4	56.8	66.6	70.9	70.0	61.2	49.1	36.6	26.0	28
Gunnison	7.2	12.4	25.6	39.2	47.6	57.6	61.4	59.8	52.0	41.4	27.6	10.8	29
Hamps	27.0	27.5	36.0	44.9	53.4	62.4	67.6	66.8	58.8	47.4	36.3	27.0	27
Hoehne	32.2	33.2	40.8	48.4	56.7	66.8	71.4	70.2	63.2	52.3	42.4	31.1	21
Holyoke	28.6	26.8	37.2	47.2	57.2	66.9	73.1	71.8	62.8	50.0	39.0	26.8	14
Las Animas	27.0	29.2	42.1	51.4	61.0	71.8	76.0	72.8	66.1	53.2	40.2	29.7	36
Lay	18.4	20.8	32.1	41.4	49.8	59.4	66.6	65.0	55.6	44.1	32.3	20.6	25
Meeker	20.5	24.0	34.2	43.0	51.1	59.2	64.8	63.4	55.2	44.1	33.2	20.9	29
Pueblo	30.8	32.3	41.4	49.8	59.0	69.0	74.0	73.3	64.8	52.5	40.3	31.8	34
Saguache	21.5	27.0	35.4	44.3	52.0	60.8	65.5	63.9	57.0	46.8	34.8	22.4	27
San Luis	21.0	25.8	34.2	41.7	49.3	57.8	62.4	61.4	54.8	44.4	33.2	22.5	29
Two Buttes	31.4	32.6	42.5	51.4	61.1	71.2	76.2	75.2	67.6	55.1	42.8	32.2	29
Wray	29.2	30.4	39.8	48.8	59.0	69.4	74.4	73.1	64.4	51.8	39.4	29.5	25

CONNECTICUT

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Cream Hill	23.1	21.6	32.7	43.0	55.2	63.8	69.2	66.4	60.9	50.9	36.9	25.7	20
Hartford	27.6	25.7	36.4	47.3	58.5	66.7	72.8	70.2	63.4	53.9	41.5	30.8	16
New Haven	29.2	28.9	36.0	46.9	57.8	66.5	71.9	70.0	63.7	53.4	41.9	32.2	48
Grosvenor Dale	24.3	23.0	34.6	45.4	56.6	64.4	70.6	68.2	58.4	51.2	39.0	28.0	18

FLORIDA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Avon Park	62.6	63.2	68.8	71.9	77.0	80.0	81.4	81.6	80.2	75.2	68.1	62.6	21
Clermont	60.9	62.5	68.8	72.3	78.2	81.6	83.0	83.0	80.8	75.2	67.9	61.4	28
Fort Meyers	63.0	64.2	68.6	71.8	76.6	79.4	80.6	81.0	79.8	75.4	69.0	63.7	29
Fort Pierce	64.0	64.4	68.5	71.4	75.9	79.3	80.8	81.4	80.2	76.4	69.4	64.1	19
Jacksonville	55.8	57.6	63.2	68.6	74.8	80.0	81.9	81.6	78.4	70.8	62.5	56.4	50
Key West	70.0	70.6	72.8	75.6	79.0	81.9	83.5	83.6	82.2	79.0	74.2	70.2	50
Lake City	55.6	56.9	64.4	68.8	75.5	79.7	81.0	81.1	78.6	70.6	62.0	56.0	31
Miami	67.0	67.6	71.1	73.6	77.8	80.2	81.7	82.0	81.0	77.8	72.8	68.4	25
Ocala	58.0	58.9	65.4	69.3	75.8	79.9	81.0	81.2	79.0	72.1	63.4	57.8	25
Pensacola	53.0	55.0	60.8	66.8	73.6	79.4	80.8	80.8	78.2	69.6	60.4	54.4	44
St. Augustine	57.0	58.0	63.6	68.1	74.0	78.9	80.8	80.6	78.8	73.2	64.3	58.0	34
Tallahassee	53.7	54.5	62.2	67.2	74.6	79.4	80.2	80.1	77.4	69.4	60.2	53.6	25
Tampa	60.8	62.7	67.0	71.6	76.6	80.0	81.1	81.2	79.8	74.2	67.2	61.7	66
Titusville	60.4	61.9	65.1	69.4	75.0	78.8	81.0	81.3	79.4	74.0	66.4	61.3	28

GEORGIA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Alapaha	50.4	52.0	59.8	66.2	74.1	79.7	81.3	80.9	76.9	67.4	57.5	50.7	35
Albany	49.9	51.5	60.3	66.7	74.7	80.8	82.2	81.6	77.6	67.9	57.8	50.8	34
Americus	48.3	50.3	58.5	65.1	73.6	79.9	81.4	80.8	76.5	66.7	56.1	49.0	37
Athens	42.5	44.4	52.3	60.8	70.0	76.7	79.0	78.0	72.7	62.0	51.5	43.6	38
Atlanta	43.0	45.1	52.5	60.6	69.2	75.8	78.4	77.2	72.2	61.9	51.8	44.4	55
Augusta	47.1	49.9	56.2	64.2	72.5	78.8	81.3	79.8	74.8	64.5	54.3	47.3	75
Eastman	49.6	50.1	59.5	65.9	74.0	80.0	81.6	80.9	76.7	66.7	56.7	48.8	30
Fort Gaines	49.0	50.4	59.3	65.7	73.9	80.0	81.4	80.8	76.7	66.8	56.7	49.8	34
Gainesville	41.2	42.4	51.5	59.2	68.1	74.8	77.7	76.2	71.0	60.8	50.6	42.0	39
Griffin	44.7	45.9	55.8	62.8	71.2	77.8	79.8	78.8	74.3	63.8	53.7	45.1	32
Louisville	47.2	48.8	57.0	63.9	73.0	78.7	80.5	80.0	75.4	65.1	54.7	47.5	31
Macon	47.3	48.5	56.6	63.9	72.3	78.8	81.1	80.0	75.3	64.8	54.2	46.7	40
Newnan	44.1	44.8	54.8	61.4	70.9	77.7	79.6	78.7	73.9	63.4	53.1	44.4	33
Rome	41.5	43.8	52.4	60.7	69.7	76.5	79.2	78.4	72.9	62.2	50.3	42.5	39
Savannah	51.8	53.7	59.6	66.3	73.8	79.2	81.5	80.7	76.4	67.3	58.3	52.2	70
Thomasville	52.5	53.8	61.1	66.8	74.6	79.9	81.4	81.1	77.4	68.4	58.8	52.4	39
Waycross	52.0	52.8	61.2	67.0	74.6	80.1	81.9	81.4	77.5	68.7	58.7	51.5	2

IDAHO

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Ashton	18.6	21.4	29.0	41.0	48.6	57.0	64.4	63.4	54.4	43.3	32.2	20.5	24
Boise	29.6	34.7	44.0	50.5	57.4	65.1	73.1	71.9	61.6	51.0	40.4	32.4	58
Buhl	28.4	32.9	40.7	49.2	55.4	64.0	73.2	70.6	60.8	49.0	39.4	29.4	15
Cambridge	21.9	27.6	37.8	49.2	55.6	64.0	72.4	71.0	59.8	48.9	37.8	25.5	26
Idaho Falls	21.0	25.6	35.4	45.1	52.4	60.4	68.1	65.8	56.8	45.7	34.2	23.0	16
Koosjia	26.8	33.5	42.6	50.0	55.8	63.6	71.4	69.6	60.6	49.0	39.2	30.5	12
Lakeview	27.2	30.0	36.2	45.1	51.8	58.5	64.2	63.6	55.0	45.8	36.6	30.8	20
Lewiston	33.1	37.4	45.4	52.6	59.0	66.2	74.7	73.4	63.4	52.6	42.4	35.4	20
Mackay	17.0	20.1	30.5	41.9	49.5	57.8	66.4	64.6	55.2	43.4	31.2	19.4	13
Oakley	28.6	31.3	38.6	46.7	53.4	62.2	70.4	69.4	59.4	48.9	38.4	29.2	28
Payette	28.6	34.2	42.6	51.2	58.2	65.8	73.3	72.0	61.4	50.8	39.9	30.2	28
Pocatello	26.5	29.4	37.9	46.2	53.5	62.6	70.9	69.3	59.8	48.4	38.0	27.3	21
Pollock	34.6	38.0	42.7	50.4	56.3	61.9	70.8	69.8	60.2	52.0	42.0	35.6	15
Porthill	23.4	26.8	35.0	45.4	53.0	59.0	65.0	63.6	53.9	44.8	33.7	27.4	28
St. Maries	28.7	32.4	39.2	46.8	53.6	60.3	66.0	64.6	57.0	48.2	37.9	31.2	22
Salmon	17.8	24.1	35.0	45.7	52.3	59.7	67.0	64.4	56.0	44.4	32.5	19.9	14

ILLINOIS

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Cairo	35.7	37.8	47.6	58.3	67.6	75.5	79.1	77.6	71.0	59.9	47.7	38.5	49
Carlinville	28.6	29.8	42.7	53.9	64.0	73.0	76.8	75.7	69.0	56.5	43.3	32.0	30
Charleston	28.2	29.6	41.2	52.9	63.4	72.6	76.5	74.3	68.3	55.7	42.6	32.0	35
Chicago	24.3	25.9	35.6	46.7	57.0	66.9	72.7	71.6	64.9	53.6	39.8	29.1	50
Dixon	20.0	21.5	35.2	48.6	59.6	69.1	73.9	71.8	64.2	51.7	37.4	25.0	30
Flora	31.2	31.0	43.2	54.3	63.8	72.6	77.0	75.0	68.2	56.3	43.4	34.0	33
Galva	21.8	22.6	37.3	49.2	60.8	70.0	74.8	72.7	65.3	53.4	38.7	25.9	28
Griggsville	27.0	28.9	41.5	53.7	63.9	72.7	76.9	75.2	67.9	56.2	42.8	31.3	34
McLeansboro	31.6	34.0	44.7	55.4	65.2	74.2	77.9	76.1	69.8	57.8	45.4	35.8	38
Marengo	18.8	21.1	31.8	45.9	57.4	67.1	71.8	69.6	61.9	49.4	35.0	23.5	60
Peoria	23.6	26.9	37.2	49.9	61.1	70.2	74.3	72.4	64.9	52.7	38.7	27.9	65
Pontiac	25.3	26.6	39.0	50.7	61.6	70.7	75.8	73.6	66.4	54.0	41.5	29.4	22
Sparta	32.4	33.5	45.1	55.8	65.4	74.1	77.8	76.1	69.7	57.9	45.5	35.5	34
Springfield	26.9	29.0	40.5	52.8	63.2	72.3	76.6	74.6	67.3	55.9	42.5	31.4	41
Urbana	25.6	26.8	40.0	49.6	61.1	69.7	74.5	72.9	65.8	54.2	41.7	28.8	18

INDIANA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Cambridge City	27.2	27.2	39.9	49.8	60.6	69.2	73.6	71.4	65.1	53.0	40.6	30.0	30
Elliston	29.5	31.7	43.4	54.0	63.7	74.3	75.7	73.9	67.7	56.0	43.7	33.3	39
Evansville	34.4	34.5	45.0	55.8	66.8	75.4	79.1	77.6	71.7	60.0	47.4	37.2	26
Fort Wayne	26.2	25.8	38.5	49.6	60.8	69.9	73.9	71.3	65.2	53.8	40.8	28.3	25
Indianapolis	28.6	30.4	40.6	52.2	63.1	72.1	76.1	73.9	67.1	55.4	42.1	32.6	52
Lafayette	25.6	27.1	38.6	50.5	61.7	70.9	74.9	72.8	66.2	53.9	40.4	29.6	43
Logansport	25.2	28.3	37.8	50.8	62.7	71.2	75.4	72.8	65.9	53.2	40.6	29.2	34
Marengo	32.3	34.4	45.0	55.0	64.4	75.4	76.1	74.5	68.6	56.7	45.3	35.1	39
Scottsburg	33.0	33.0	45.3	54.8	65.5	74.0	78.4	75.9	69.7	57.3	45.1	34.8	28
South Bend	24.4	23.6	36.7	48.3	60.0	68.9	73.3	71.6	65.4	53.4	40.0	27.9	29
Terre Haute	30.3	30.5	43.6	53.9	65.0	73.5	77.5	75.7	69.4	57.5	44.5	33.0	30
Valparaiso	23.8	23.7	36.4	48.4	58.2	64.6	72.7	70.8	65.1	53.4	38.8	27.5	23
Vevay	32.7	34.0	42.7	53.8	65.3	73.8	77.5	75.5	69.6	57.5	45.6	36.1	40

IOWA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Algona	15.7	17.5	32.1	47.5	58.8	68.6	73.1	70.8	62.5	50.2	34.1	21.0	29
Charles City	14.2	16.4	31.8	46.4	57.9	67.2	72.3	69.9	62.0	49.7	33.8	21.0	29
Clarinda	21.9	23.5	37.1	50.3	61.0	71.0	75.9	74.2	65.9	53.6	38.7	25.8	31
Corydon	23.2	24.1	38.3	50.0	61.1	70.2	75.3	74.1	64.8	54.8	40.1	26.4	27
Cresco	10.6	14.7	27.1	44.4	56.5	65.7	70.6	69.0	59.9	47.1	29.7	18.2	33
Davenport	21.4	24.3	36.2	49.9	61.2	70.6	75.5	73.2	65.3	53.3	38.5	27.1	49
Denison	19.8	20.5	35.1	48.6	59.3	68.5	73.4	71.8	63.7	52.2	36.8	23.8	25
Des Moines	20.1	23.1	36.3	50.3	61.2	70.5	75.4	73.3	65.1	53.5	38.4	25.8	42
Dubuque	18.5	21.5	34.1	48.7	60.2	69.1	74.1	71.7	63.8	51.3	36.8	24.9	47
Greenfield	20.8	21.8	35.8	49.6	60.4	70.0	74.4	72.8	65.0	53.0	37.8	25.5	25
Independence	16.7	18.6	34.0	47.5	58.8	67.4	72.6	70.5	62.9	51.1	35.8	22.8	27
Keokuk	24.2	27.2	38.8	52.7	63.0	72.6	77.0	75.4	67.2	57.0	41.8	30.2	49
Logan	21.0	22.8	36.5	50.6	61.0	70.3	74.9	73.2	65.1	52.7	37.7	25.1	31
Marshalltown	18.6	19.9	34.7	48.5	60.0	69.0	74.1	72.2	64.1	52.1	37.1	23.1	26
Rockwell City	18.4	19.5	34.6	47.4	59.2	69.0	73.8	71.7	63.4	51.7	36.4	22.4	24
Sibley	15.3	16.3	30.6	45.8	56.7	66.0	70.3	68.9	60.5	48.7	33.7	19.2	25
Sioux City	18.7	20.0	33.8	48.7	59.7	69.4	74.4	72.1	63.9	51.6	36.0	24.2	28
Washington	21.4	22.9	37.3	50.2	61.1	70.1	74.7	72.9	65.1	53.4	38.7	25.7	28

KANSAS

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Colby	28.8	30.4	40.1	50.2	59.7	70.1	75.7	75.0	66.3	53.7	41.1	29.5	25
Concordia	24.4	28.8	40.7	53.6	63.7	72.7	78.1	76.5	68.1	55.4	39.9	29.2	25
Dodge City	29.0	33.2	42.8	53.6	63.5	72.5	78.4	77.7	69.4	56.1	42.6	32.6	25
Ellenwood	30.5	32.5	44.4	54.2	63.7	73.5	78.1	77.2	69.4	57.7	44.1	33.1	25
Emporia	34.0	32.5	45.3	54.5	64.4	73.3	78.2	77.4	69.7	58.2	45.8	32.8	25
Hanover	27.4	30.1	43.0	52.8	63.0	73.0	79.0	77.0	68.7	57.3	43.1	29.7	25
Hays	29.8	31.0	42.3	51.8	61.6	71.9	77.9	77.2	68.3	56.0	42.4	32.4	25
Healy	28.9	32.2	42.5	51.8	61.5	71.4	76.5	76.3	68.2	55.5	42.7	30.4	25
Horton	27.2	28.3	41.8	52.2	62.6	72.1	76.7	76.0	67.8	56.5	42.7	31.1	25
Independence	34.6	35.9	48.5	57.4	66.0	75.3	80.1	80.0	72.7	60.6	48.4	36.3	25
Iola	27.6	32.0	42.4	54.2	64.5	73.4	78.1	76.3	68.0	56.9	43.0	32.5	25
Medicine Lodge	33.0	35.4	47.4	56.9	66.0	75.6	80.5	79.9	72.0	59.8	47.0	34.1	25
Phillipsburg	27.9	28.3	40.4	51.9	61.9	72.8	77.9	77.6	68.6	56.2	44.4	29.6	25
Salina	29.1	31.0	44.0	54.3	64.2	73.8	79.3	78.8	70.5	57.8	44.0	31.0	25
Topeka	25.6	30.0	40.9	53.9	63.5	72.6	77.6	76.0	68.3	56.3	41.7	31.1	25
Ulysses	31.0	32.8	43.9	53.0	62.0	73.1	77.7	77.6	69.5	56.8	42.9	31.2	25
Wichita	29.7	33.0	44.1	56.6	65.9	74.3	79.0	77.5	69.8	58.8	43.8	34.2	25

KENTUCKY

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Alpha	40.0	39.5	50.1	58.0	66.4	72.2	75.8	75.3	70.0	50.7	49.7	40.6	21
Beattyville	34.6	35.7	45.8	54.5	64.4	72.6	75.8	75.0	69.7	57.8	45.2	35.8	18
Blandville	35.8	36.2	48.4	57.2	66.8	74.8	78.1	76.8	71.0	59.6	48.2	37.6	28
Bowling Green	37.1	37.6	49.0	57.7	68.0	75.9	79.2	77.8	72.2	59.8	48.0	38.0	27
Earlington	35.4	35.6	48.0	57.0	67.4	75.6	78.6	76.8	71.4	59.4	47.8	37.6	28
Eubank	34.8	34.8	46.2	54.4	64.0	71.5	74.9	73.8	68.4	57.0	45.1	36.1	25
Irvington	35.7	35.2	47.5	55.4	66.4	74.1	77.4	76.0	70.6	59.2	46.7	36.6	25
Lexington	33.6	34.0	44.1	53.6	64.2	72.6	75.9	74.4	69.0	57.1	44.6	35.8	39
Loretto	36.4	34.6	47.2	55.2	65.6	72.6	76.2	75.6	69.9	58.2	46.5	35.7	20
Louisville	34.7	36.4	46.0	56.2	66.2	74.9	78.6	76.9	70.9	58.9	46.6	36.9	44
Maysville	32.7	32.3	44.9	53.4	64.6	72.9	77.1	75.6	69.6	57.6	44.8	34.1	21
Middlesboro	37.8	39.0	49.0	56.8	64.0	71.1	75.3	74.4	69.6	58.6	46.4	40.6	23
Scott	32.4	31.7	44.2	53.0	64.0	71.7	76.2	74.9	69.2	57.8	44.9	33.6	25

[1] University of Arizona.

AVERAGE MONTHLY TEMPERATURES AT SELECTED STATIONS—Continued.

[Monthly mean temperatures]

LOUISIANA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Alexandria	49.2	51.1	59.9	66.8	73.6	80.1	82.1	81.9	77.1	66.3	57.3	49.6	31
Amite	51.4	53.2	61.2	66.9	73.5	79.8	81.2	81.2	77.1	66.6	58.1	51.6	31
Calhoun	47.0	48.4	56.8	64.1	71.7	79.0	81.3	80.8	75.3	64.7	54.9	47.2	31
Cheneyville	50.2	52.0	60.7	67.0	73.6	79.9	81.7	81.4	76.8	66.4	58.3	50.5	31
Grand Couteau	53.2	54.9	62.3	68.4	74.2	79.9	81.7	81.3	77.6	67.6	59.5	53.9	34
Lake Charles	51.8	53.7	60.9	67.2	73.6	80.0	81.5	81.5	77.7	68.3	59.6	52.8	31
New Orleans	54.3	56.8	63.1	68.7	75.2	80.8	82.3	82.2	79.0	70.5	61.6	55.3	48
Shreveport	47.1	50.3	58.5	66.0	73.3	80.4	82.9	82.2	76.6	66.3	56.0	48.9	47

MAINE

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Eastport	20.5	21.0	29.2	38.8	47.5	55.0	60.4	60.6	55.8	47.5	36.9	25.4	47
Greenville	12.8	12.4	23.5	36.4	49.5	58.9	65.4	62.5	55.0	45.6	30.7	18.0	15
Portland	22.4	23.3	32.2	43.6	54.4	63.7	69.8	67.8	61.0	50.7	39.0	27.8	46
Presque Isle	10.5	11.0	24.5	40.2	51.4	57.3	64.2	64.6	53.6	45.8	28.2	16.4	11

MARYLAND

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Baltimore	34.2	34.9	42.4	53.4	64.3	72.7	77.4	75.3	68.6	57.8	46.1	36.8	50
Cumberland	31.0	32.7	39.5	51.8	62.8	70.3	73.9	72.0	65.0	54.3	42.3	33.7	37
Frederick	32.1	32.6	41.9	52.6	63.5	71.7	76.2	73.9	67.1	55.7	43.9	34.5	46
Princess Anne	37.0	36.7	45.5	54.4	63.2	71.1	76.2	74.7	68.7	57.8	47.3	38.8	45
Washington, D. C	33.7	34.7	42.6	53.4	64.2	72.4	76.8	74.7	68.0	56.9	45.2	36.1	50

MASSACHUSETTS

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Boston	27.9	27.8	35.7	46.0	57.1	66.3	72.0	69.9	63.4	53.3	41.9	31.9	49
Nantucket	31.9	30.2	36.0	43.7	52.6	60.9	67.7	67.6	62.9	54.2	44.7	35.8	34
Williamstown	22.5	21.4	32.3	43.9	55.6	63.5	68.6	66.2	59.2	49.6	37.1	25.8	18

MICHIGAN

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Alpena	18.8	17.4	25.5	38.8	50.2	60.4	65.9	63.9	57.8	47.0	34.7	24.7	46
Big Rapids	20.2	18.3	29.8	43.8	55.0	64.4	69.0	66.4	59.4	48.0	35.9	35.0	27
Cheboygan	17.7	15.5	25.8	40.3	50.8	61.9	67.0	65.0	59.2	47.9	34.7	23.7	30
Detroit	24.6	24.5	33.6	45.9	57.7	67.2	72.2	70.2	63.6	52.1	39.1	29.1	50
Escanaba	15.1	14.6	24.3	37.9	49.0	60.5	66.0	64.0	57.2	46.2	33.6	23.6	38
Ewen	10.8	10.7	23.4	38.7	50.5	60.4	65.0	61.3	54.8	44.6	30.6	16.4	22
Grand Haven	24.2	23.5	31.6	43.7	54.1	63.7	68.7	67.0	61.0	50.3	38.4	29.4	48
Kalamazoo	23.3	23.3	34.2	46.7	57.8	67.6	72.3	70.1	63.1	51.1	38.0	27.3	45
Lansing	21.9	22.1	31.6	45.6	57.6	66.9	71.0	68.5	61.2	49.5	36.3	26.0	57
Marquette	16.6	16.4	24.7	38.2	49.0	58.8	65.4	63.6	57.5	46.7	33.0	23.0	47
Omer	19.0	16.9	28.7	42.0	52.9	63.7	68.2	65.7	59.7	49.4	36.3	24.6	24
Sault Ste. Marie	14.0	11.9	22.6	37.7	48.8	58.7	63.3	62.0	55.8	44.9	32.4	20.8	33
Traverse City	22.1	19.2	29.5	41.5	52.1	63.0	69.1	67.4	60.8	50.2	37.7	27.6	27

MINNESOTA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Alexandria	6.8	9.4	25.4	42.3	54.6	64.5	69.5	67.0	58.4	46.2	29.6	13.5	27
Bird Island	11.1	13.3	28.6	44.6	56.7	65.6	71.0	68.6	61.0	47.8	31.4	17.3	31
Collegeville	11.7	14.1	28.3	44.6	56.0	65.7	70.8	68.1	60.0	47.6	31.6	17.6	28
Duluth	9.3	12.4	23.8	38.0	48.1	58.4	65.4	63.8	56.3	45.0	29.6	16.9	47
Fairmont	13.2	15.8	30.4	45.6	57.0	66.6	71.6	69.6	61.3	49.2	32.8	20.0	30
International Falls	2.5	6.2	20.4	39.4	51.4	62.2	66.6	62.9	55.6	42.4	25.6	9.9	17
Montevideo	11.4	13.6	28.4	45.4	57.0	66.4	71.2	68.7	61.2	48.1	32.0	17.6	30
Park Rapids	3.7	6.4	22.4	40.2	52.1	63.0	67.7	64.3	55.6	43.0	26.6	11.4	29
Pine River Dam	5.4	7.1	23.8	40.6	52.8	62.8	68.3	65.6	57.1	45.2	29.4	12.3	24
Roseau	−0.4	2.0	20.1	40.0	52.0	61.2	65.4	62.1	54.2	41.4	23.9	7.6	16
St. Paul	12.3	16.2	29.3	46.2	57.6	67.2	72.0	69.5	61.0	48.6	32.3	19.4	46
Worthington	13.0	14.6	28.9	44.3	55.9	65.0	70.2	68.3	60.2	47.6	32.0	18.8	26

MISSISSIPPI

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Bay St. Louis	52.0	53.7	62.0	67.4	74.6	80.3	81.3	81.6	79.0	69.4	60.0	52.5	28
Booneville	41.6	42.8	52.5	60.6	69.0	76.9	79.4	78.8	73.6	62.2	51.2	42.2	25
Brookhaven	48.5	50.6	59.1	65.5	72.9	79.6	81.5	81.1	76.6	66.1	56.5	49.4	33
Duckhill	45.0	46.2	55.8	62.4	70.3	77.0	79.7	79.4	74.3	63.3	53.3	45.2	22
Hattiesburg	49.7	51.7	60.4	65.6	73.4	80.4	81.9	81.6	77.1	66.1	57.2	50.3	28
Holly Springs	39.9	40.6	51.7	60.0	69.3	77.4	79.9	79.2	74.0	62.3	50.5	40.6	30
Lake	56.7	47.9	57.0	63.8	71.0	77.9	79.9	79.3	74.7	63.2	53.6	46.8	33
Louisville	46.0	47.2	56.1	62.7	70.4	77.7	79.4	79.8	75.2	64.6	54.4	46.6	30
Meridian	47.2	48.7	57.1	64.2	71.5	78.1	79.7	79.5	74.9	64.3	54.6	47.3	31
Natchez	49.9	51.5	60.4	66.7	73.4	79.6	81.6	81.6	77.4	67.1	57.9	49.9	33
Vicksburg	48.2	51.3	58.7	65.6	72.8	79.3	81.3	80.9	76.2	66.5	56.6	49.8	49

MISSOURI

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Arcadia	32.1	33.5	44.8	55.3	64.6	72.0	75.9	74.5	67.6	56.1	44.0	34.3	40
Bethany	24.6	27.0	40.0	51.2	62.6	72.4	76.0	74.9	67.0	54.7	42.9	30.3	31
Brunswick	26.8	29.1	41.9	54.1	64.3	73.2	75.7	73.8	66.7	55.2	41.5	30.6	42
Clinton	31.4	31.9	44.3	55.7	65.2	73.4	77.5	76.8	70.2	58.6	47.3	34.4	28
Columbia	30.0	31.0	43.5	54.5	64.4	73.4	77.0	76.0	68.9	57.3	44.2	33.3	33
Hannibal	27.7	28.4	42.3	53.3	63.9	73.0	76.9	75.4	68.2	56.5	42.9	31.1	31
Kansas City	29.7	30.8	43.2	54.9	64.6	73.9	78.2	76.8	69.4	58.1	44.6	33.3	34
Lebanon	33.0	33.9	45.4	55.7	65.6	73.1	76.9	76.3	69.5	58.0	46.0	35.0	34
Rolla	31.3	35.2	45.0	55.0	64.5	72.8	77.4	75.8	68.0	55.9	44.9	33.6	21
St. Louis	30.8	34.5	43.8	55.8	66.9	74.8	78.6	77.3	70.1	58.4	45.1	34.8	41
Springfield	33.6	33.7	44.8	56.1	64.6	72.6	76.3	75.7	69.5	58.0	46.2	36.2	33
Unionville	23.5	25.4	38.6	50.7	62.4	71.8	76.6	75.0	67.2	55.4	40.2	27.4	30

MONTANA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Augusta	20.8	22.3	29.2	41.9	48.9	56.6	62.3	60.7	52.0	45.0	32.3	26.2	21
Billings	22.5	25.0	34.2	47.2	54.8	63.0	70.8	68.9	58.7	48.1	34.7	26.5	26
Como	26.0	29.1	37.2	45.4	51.6	59.6	65.8	63.9	54.5	45.5	35.7	26.0	13
Crow Agency	18.6	20.2	32.6	46.4	56.7	65.0	71.2	69.1	58.7	47.1	33.3	24.5	37
Cut Bank	14.6	16.8	29.2	42.2	48.5	59.2	65.2	63.0	52.5	42.5	30.6	23.0	12
Fort Benton	20.6	21.2	30.6	45.2	53.6	61.6	67.8	65.6	56.2	47.8	33.2	26.0	16
Fort Logan	18.9	20.6	27.5	39.1	48.1	55.9	63.1	61.6	51.1	41.2	27.7	20.5	24
Havre	12.6	13.2	27.3	44.0	53.1	60.2	68.0	66.0	56.0	45.0	30.3	20.4	40
Helena	20.3	23.0	32.2	43.7	51.4	59.6	67.0	66.1	55.7	45.4	32.7	25.0	42
Jordan	13.2	16.6	29.6	42.9	51.8	62.8	71.6	67.8	57.1	45.0	30.5	18.3	11
Kalispell	22.0	24.2	33.1	43.8	51.3	58.1	64.5	62.8	53.2	43.6	32.7	24.9	25
Malta	10.0	12.6	25.1	44.2	54.0	63.8	69.8	67.9	57.0	44.4	29.6	15.3	15
Miles City	15.3	16.9	31.1	46.6	56.7	66.4	73.6	71.7	60.1	47.4	32.9	21.6	44
Missoula	21.8	25.8	35.2	44.9	52.4	59.4	66.9	65.2	55.4	44.8	33.1	24.6	29
Poplar	6.1	8.6	23.8	43.8	54.9	62.7	70.6	67.9	57.2	44.7	27.7	14.7	36
Red Lodge	20.9	20.7	27.9	38.6	45.9	55.7	61.4	60.2	51.2	51.0	31.5	23.3	21
Springbrook	14.1	15.3	27.7	43.7	52.8	62.9	68.6	66.8	58.0	45.6	31.9	19.3	20
Valentine	14.8	17.8	30.4	42.9	52.2	62.2	69.2	67.0	55.5	45.0	31.9	20.1	14
Wibaux	15.7	16.2	25.9	43.0	54.1	61.0	68.6	65.6	55.4	43.7	28.6	18.4	14

NEBRASKA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Atkinson	19.3	20.9	33.4	46.7	57.3	67.6	73.6	71.0	63.1	50.2	35.2	23.3	32
Curtis	26.2	27.2	38.3	50.3	60.6	69.8	75.4	73.9	64.7	51.7	38.5	27.4	24
Fort Robinson	23.0	23.2	33.5	45.8	54.5	65.0	71.1	69.8	60.6	47.7	35.6	26.5	36
Halsey	22.7	25.5	36.8	47.5	56.3	68.2	73.5	71.8	63.3	50.2	37.5	25.5	18
Hartington	18.7	19.9	33.4	45.6	58.4	68.2	73.5	71.3	62.9	51.4	35.3	23.2	29
Kennedy	23.0	23.0	33.1	46.8	57.6	66.7	72.5	71.3	62.2	49.1	32.4	28.7	17
Kimball	26.8	27.2	35.0	45.2	54.6	65.2	71.0	69.7	60.8	48.0	36.4	28.7	31
Lincoln	22.7	24.6	37.9	51.1	61.8	71.5	76.6	75.1	66.6	54.7	39.9	28.5	38
Madison	21.3	22.2	34.8	47.9	59.0	68.4	73.9	71.7	63.4	51.4	36.5	24.3	25
Minden	22.9	25.3	36.9	50.0	59.9	70.1	75.4	73.7	65.2	52.5	38.0	27.3	37
North Platte	23.0	27.4	36.4	48.6	58.5	68.2	73.8	72.3	63.5	50.7	37.0	27.2	46
Omaha	21.3	24.8	37.0	51.2	62.3	71.6	76.6	74.6	66.1	54.4	39.0	27.1	47
Scotts Bluff	25.9	26.0	35.3	46.4	55.4	66.3	72.2	71.1	61.8	49.0	36.8	28.1	30
Valentine	21.1	21.3	34.3	46.1	56.0	66.5	72.8	70.9	61.9	49.0	34.6	25.2	32

NEVADA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Austin	27.6	30.6	35.6	44.2	50.7	60.2	69.2	68.1	58.4	47.7	38.4	30.0	29
Belmont	25.4	27.4	33.6	41.4	49.7	60.3	67.8	66.1	56.2	46.4	37.6	27.6	18
Eureka	27.8	30.4	36.8	45.2	51.0	61.0	70.4	69.6	60.5	39.2	38.7	30.2	22
Fallon	30.0	35.6	42.4	50.4	56.6	65.2	73.0	71.8	61.2	50.0	39.9	31.2	26
Las Vegas	43.1	47.0	53.2	62.2	68.1	77.3	83.2	81.8	73.6	62.2	51.2	42.1	18
Logandale	43.9	49.2	55.6	63.9	71.1	80.6	86.6	85.7	77.1	65.4	52.8	43.6	20
McGill	26.6	29.6	35.7	45.2	52.6	61.2	69.2	68.2	59.0	46.0	37.0	26.6	19
Minden	30.7	36.0	41.8	48.2	54.0	61.2	67.3	66.9	59.7	49.8	42.2	32.7	33
Quinn River Ranch	26.6	30.9	40.8	46.8	53.8	61.8	69.6	67.2	57.8	46.6	37.2	27.3	20
Reno	31.4	35.6	40.7	47.2	53.2	62.0	69.5	68.6	60.2	50.4	41.2	33.6	33
Tecoma	23.3	27.4	36.7	45.7	52.8	61.7	69.8	66.5	57.2	45.5	33.8	24.8	19
Thorne	33.8	37.0	44.2	50.2	59.0	66.8	74.8	74.2	64.6	53.5	43.6	35.4	23
Tonopah	30.4	33.6	40.0	47.3	53.7	64.8	72.8	71.7	62.5	50.8	40.9	30.7	14
Winnemucca	28.2	33.3	40.0	46.8	53.9	62.7	70.9	69.3	59.2	48.2	37.8	30.2	42

NEW HAMPSHIRE

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Concord	21.5	20.7	32.4	42.7	55.4	63.2	69.8	66.5	59.4	49.4	36.8	25.2	18
Hanover	17.3	17.6	28.0	42.3	54.8	62.6	68.9	66.0	58.8	48.3	34.4	21.1	20

NEW JERSEY

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Atlantic City	33.0	32.7	39.0	47.7	57.9	66.8	72.4	72.3	67.0	56.8	45.4	36.2	47
Trenton	32.3	31.4	41.3	51.6	62.4	70.3	75.8	73.7	67.4	57.2	45.4	35.0	27
Vineland	32.2	32.5	40.5	51.0	62.3	71.2	76.2	73.7	67.0	56.0	44.1	34.5	51

NEW MEXICO

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Agricultural College	42.3	46.3	53.2	60.7	69.3	78.3	80.5	78.7	72.3	61.6	49.4	42.2	58
Albuquerque	35.2	40.3	48.0	55.4	63.7	73.0	76.0	74.2	67.7	56.2	44.0	35.2	21
Alma	38.0	41.5	46.9	53.3	60.7	69.3	74.1	72.8	66.9	55.8	45.6	37.4	22
Chama	23.4	25.1	32.2	42.0	48.6	58.2	63.2	62.6	55.6	46.1	35.8	24.7	19
Clayton	35.1	37.6	43.4	51.5	60.0	69.6	73.4	72.6	66.3	55.4	44.2	33.2	16
Clovis	35.6	40.6	46.4	54.9	65.3	73.6	78.0	75.8	70.1	58.2	45.4	35.2	10
Corona	33.5	38.6	43.2	49.4	57.6	66.6	69.5	68.2	63.0	53.0	43.0	34.9	10
Cuervo	38.8	41.6	48.8	55.8	66.1	74.4	78.8	75.8	69.8	58.8	47.8	37.6	12
Fort Bayard	38.7	40.7	46.1	52.8	61.2	70.8	72.4	70.9	66.1	56.5	46.2	39.0	46
Fort Stanton	35.4	38.4	43.7	50.9	58.7	67.0	69.0	67.1	61.3	51.9	41.8	35.5	42
Fort Sumner	38.0	42.2	49.2	55.8	65.8	74.4	77.9	76.8	69.1	56.9	46.4	37.2	11
Fort Union	32.2	33.1	39.2	45.2	53.2	62.0	65.9	65.0	58.7	49.0	40.4	31.2	23
Fort Wingate	32.1	35.6	40.6	47.8	55.2	65.4	69.6	68.3	62.0	51.3	42.0	32.3	14
Haynes	23.0	28.8	36.6	42.6	52.8	63.2	68.6	66.8	59.5	48.2	36.7	23.6	9
Lovington	42.2	45.0	48.4	59.5	67.0	75.6	77.8	76.9	70.9	59.5	48.5	40.8	13
Roswell	40.1	43.3	51.4	58.3	66.5	75.2	77.7	76.3	69.7	57.9	47.2	38.5	27
San Jon	38.2	41.4	48.6	55.9	64.8	74.0	78.4	76.8	70.7	59.2	47.2	37.1	15
San Marcial	38.4	44.0	51.4	58.4	65.9	74.7	77.8	76.9	69.8	57.7	46.8	36.9	25
Santa Fe	29.2	32.8	40.0	46.9	55.4	64.9	68.6	67.4	61.0	50.2	39.0	30.4	48
Socorro	38.1	43.3	49.5	57.0	65.1	74.6	76.9	75.2	68.6	57.2	46.2	37.0	26
Springer	29.9	32.0	41.6	49.6	58.7	67.1	70.6	69.4	62.4	51.0	39.7	29.8	23
Taos	26.5	31.4	39.6	47.2	55.1	62.9	68.0	66.7	60.0	49.0	38.2	26.4	23

NEW YORK

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Albany	23.5	24.2	33.4	46.7	59.1	68.2	72.3	70.4	62.6	50.6	39.2	28.0	99
Angelica	23.1	21.5	30.5	43.2	54.3	63.4	67.5	65.0	58.7	47.5	36.2	26.2	35
Binghamton	24.1	22.8	32.9	45.2	56.8	65.3	69.8	67.7	61.4	50.4	38.4	27.7	30
Buffalo	25.0	23.7	31.7	42.5	54.2	64.6	69.8	68.6	62.5	51.5	39.2	29.4	50
Canton	16.0	15.6	27.0	42.6	54.5	63.9	68.6	66.1	58.6	47.2	34.5	21.5	23
Cooperstown	20.4	20.2	28.3	41.3	54.4	63.6	68.0	65.5	58.4	47.0	35.1	24.8	65
Indian Lake	16.1	15.0	26.5	38.9	51.8	59.7	65.1	62.4	56.2	45.8	32.2	20.1	21
Ithaca	24.5	24.1	32.1	44.8	57.2	66.0	70.7	68.2	61.8	50.7	38.8	28.7	42
New York City	30.8	30.7	38.0	48.8	60.0	69.0	74.3	72.7	66.6	56.1	44.4	34.2	49
Oswego	23.8	23.5	30.8	42.5	53.5	62.9	69.0	67.8	61.2	50.2	38.9	28.3	65
Rochester	24.6	23.6	31.8	44.4	56.6	66.0	20.9	68.8	62.6	51.1	38.8	28.7	49
Syracuse	23.8	21.7	32.6	44.0	56.4	64.6	70.3	67.9	61.8	51.3	38.4	27.2	18
West Point	29.7	27.7	36.1	48.0	59.4	68.6	73.2	71.3	64.1	52.9	41.5	30.9	86

NORTH CAROLINA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Asheville	38.2	38.0	47.1	54.0	62.7	68.9	71.9	71.4	66.0	56.1	45.8	38.0	18
Brewers	38.4	38.7	47.7	55.1	64.6	71.6	74.9	74.1	68.9	59.0	47.7	39.2	26
Charlotte	41.5	43.5	51.3	59.6	69.0	75.7	78.4	76.9	71.8	61.2	50.8	42.9	44
Edenton	42.6	42.2	50.9	58.5	68.4	74.8	79.2	78.4	71.8	61.5	50.9	42.8	24
Greensboro	40.1	40.8	49.7	58.0	68.0	74.8	77.8	76.6	70.7	60.4	48.6	40.5	38
Hatteras	46.0	45.9	50.0	56.5	65.8	74.2	78.0	78.0	75.8	66.8	57.2	49.1	44
Lenoir	37.3	41.1	46.9	56.2	64.9	71.8	75.1	73.8	67.4	57.1	46.4	38.7	47
Lumberton	44.2	43.6	53.6	61.6	70.8	77.1	80.1	79.2	73.4	62.7	52.1	44.2	33
New Bern	45.7	46.0	53.5	60.0	69.4	76.0	79.0	78.3	72.7	63.2	53.8	46.2	33
Raleigh	41.7	42.5	50.6	58.9	68.5	75.3	78.3	77.2	71.5	60.8	50.7	42.6	34
Southern Pines	44.0	44.3	53.6	61.3	70.4	76.9	78.9	78.5	73.3	62.8	52.8	44.8	29
Weldon	39.7	41.1	48.4	57.5	68.2	75.4	79.2	77.3	71.2	59.5	48.4	40.6	47
Wilmington	47.1	48.3	54.6	61.4	70.0	76.4	79.6	78.7	73.8	64.4	54.9	48.0	50

NORTH DAKOTA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Bismarck	6.7	9.7	23.6	43.1	54.1	63.5	69.5	67.4	57.6	44.8	27.9	14.9	43
Bottineau	−0.7	1.8	17.7	39.4	51.3	61.0	65.8	63.6	55.5	41.6	23.6	6.7	26
Crosby	1.7	7.1	22.0	40.6	50.4	60.6	65.9	63.7	53.7	41.5	27.8	12.3	11
Devils Lake	2.9	4.2	19.8	40.1	52.0	61.7	67.1	64.7	55.9	43.0	26.8	9.4	21
Dickinson	10.3	11.8	24.4	42.9	52.2	61.3	68.0	66.3	56.5	43.9	28.6	17.3	26
Garrison	6.5	8.4	21.7	42.6	52.6	62.2	68.1	65.7	56.8	43.8	27.0	13.6	23
Grand Forks	3.6	6.5	22.4	42.0	53.4	62.9	67.4	64.9	56.2	43.5	26.1	10.6	25
Jamestown	6.5	7.9	22.6	42.5	53.5	63.1	68.5	66.2	56.7	44.8	27.6	13.6	26
McKinney	3.2	5.1	19.2	41.0	52.0	60.7	66.0	63.5	54.1	41.7	24.6	10.7	25
Manfred	4.0	6.8	23.1	41.8	51.6	61.5	66.9	64.3	55.9	43.3	29.0	11.3	15
Minot	5.0	7.9	21.4	41.7	52.3	62.5	68.1	65.1	56.7	43.6	29.7	12.4	19
Mott	7.5	11.8	26.6	42.6	51.6	63.0	69.1	65.9	56.3	43.0	31.2	14.1	11
Oakdale	14.4	13.3	24.1	42.8	53.3	61.9	68.0	66.6	57.1	45.6	28.4	20.5	15
Pembina	=2.9	1.4	16.0	37.9	52.5	62.6	67.7	64.1	53.8	40.9	22.7	6.0	38
Williston	5.8	7.9	22.7	43.0	53.3	63.1	68.5	66.5	56.0	43.6	27.0	13.6	39

OHIO

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Cincinnati	32.4	33.9	43.1	53.7	64.4	73.1	77.2	75.3	68.8	57.0	44.5	35.3	48
Circleville	30.9	29.9	42.4	52.1	62.9	71.2	75.4	73.5	67.6	55.6	43.0	32.5	27
Cleveland	26.9	26.6	35.0	46.2	57.9	67.1	71.8	70.0	64.1	53.2	40.6	30.8	51
Columbus	29.1	30.0	39.9	51.0	62.2	70.9	75.1	72.8	66.6	54.9	42.0	32.2	43
Greenville	27.6	28.0	39.1	49.9	60.9	69.6	73.6	71.3	64.5	52.9	40.9	30.7	35
Millport	26.4	25.0	37.8	47.0	58.0	65.2	70.7	68.9	62.6	51.9	39.1	28.4	25
North Lewisburg	27.4	29.2	38.0	50.7	61.3	69.5	73.7	71.2	64.8	52.1	39.7	29.9	77
Portsmouth	34.7	36.7	45.0	55.5	64.9	72.6	76.6	74.3	67.9	55.9	44.8	36.5	91
Sandusky	26.9	27.1	35.5	40.8	59.1	69.0	73.6	71.9	65.3	53.6	40.8	30.7	53
Toledo	26.2	26.6	35.8	47.5	59.2	68.7	73.4	71.0	64.7	53.1	40.6	30.2	48
Wooster	26.5	26.2	36.7	47.9	58.5	67.6	71.5	69.5	63.6	51.6	40.0	30.1	36

OKLAHOMA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Ada	41.3	43.0	53.2	60.2	68.3	76.4	82.3	81.2	74.7	62.2	53.0	41.7	14
Alva	34.8	36.6	48.2	58.0	66.9	76.4	81.0	80.1	72.6	59.6	48.2	36.8	20
Ardmore	41.9	43.8	54.8	62.0	69.9	78.9	83.4	83.3	76.1	64.3	54.2	42.4	20
Bacone	38.9	40.3	52.3	60.4	68.3	76.8	80.7	81.1	74.8	62.9	52.3	40.1	22
Beaver	33.2	33.7	47.0	57.3	66.6	75.7	80.9	80.2	71.3	57.8	45.3	34.2	25
Chandler	37.2	39.1	51.6	60.1	68.4	77.6	82.4	81.6	74.0	61.6	52.3	38.7	20
Enid	35.9	36.3	49.9	57.8	66.9	76.8	81.8	81.4	74.0	60.4	49.6	36.4	23
Idabel	44.5	46.8	55.9	62.8	69.5	79.7	82.3	80.7	76.6	64.5	50.5	45.0	9
McAlester	41.0	43.6	54.6	61.6	69.6	78.5	82.7	82.0	76.3	64.3	54.0	42.8	19
Mangum	40.0	42.0	52.1	61.4	69.6	78.0	82.5	81.9	74.4	62.4	52.3	40.8	28
Marlow	39.6	41.0	53.0	60.6	68.4	77.0	81.1	81.8	74.0	62.7	54.4	40.7	20
Newkirk	35.3	36.3	49.3	58.9	67.7	77.1	82.0	81.7	73.5	61.9	49.6	36.7	24
Oklahoma City	37.1	38.5	50.0	59.6	67.4	76.1	80.2	80.1	73.4	61.6	49.7	38.7	30
Tulsa	36.5	38.7	51.0	59.1	67.7	77.4	81.6	81.5	74.7	61.6	51.0	39.1	16
Vinita	36.6	38.3	49.8	59.2	67.0	74.9	79.0	78.7	73.9	60.6	50.1	38.4	19
Weatherford	36.6	39.2	51.0	58.6	67.4	76.6	81.4	81.2	73.5	61.0	49.6	37.2	20
Woodward	35.2	37.6	48.0	58.1	68.6	76.4	81.7	80.2	72.3	59.6	48.4	35.4	20

OREGON

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Albany	39.4	42.2	46.6	51.1	56.5	61.4	66.4	66.0	59.9	52.5	45.1	40.5	40
Ashland	38.1	41.7	45.4	50.2	55.8	62.0	69.2	68.7	61.5	53.5	44.5	38.7	39
Astoria	40.1	42.2	45.3	49.0	53.3	57.4	60.7	61.1	58.6	53.5	47.0	42.2	70
Baker	25.7	29.6	36.6	44.5	51.1	57.9	66.1	65.6	56.4	47.2	36.7	27.7	30
Bend	30.5	33.0	37.8	43.8	49.6	57.2	64.2	63.3	56.6	48.0	38.6	31.5	19
Dayville	34.2	37.9	43.2	49.7	54.7	61.7	68.4	66.9	58.8	50.2	41.9	35.7	26
Diamond	29.1	30.7	35.7	43.8	50.3	56.7	63.9	62.9	53.6	45.3	37.3	29.5	10
Eugene	40.0	42.6	45.8	50.4	54.9	60.1	65.8	65.2	57.8	53.3	42.6	41.2	30
Joseph	23.7	26.2	33.1	41.9	48.7	55.1	63.3	62.6	54.0	44.7	34.4	25.4	30
Klamath Falls	28.9	32.9	38.8	46.1	52.7	59.8	67.8	67.1	58.5	49.0	38.7	31.1	30
Lakeview	27.7	30.0	35.0	43.4	49.9	58.0	65.9	66.1	56.8	48.1	37.3	29.5	29
Newport	43.8	45.1	46.0	48.4	51.6	55.0	56.8	57.3	57.0	53.5	48.9	45.2	33
Portland	39.0	42.0	47.0	51.6	57.1	62.0	67.0	66.6	61.5	54.3	46.4	41.5	51
Riverside	26.5	32.7	40.0	48.1	53.6	63.0	71.2	69.1	58.9	47.7	36.8	27.4	20
Roseburg	41.0	43.4	47.4	51.3	56.4	61.2	67.1	67.0	61.3	53.7	46.3	41.8	45
Silver Lake	27.9	31.1	35.8	42.4	49.1	55.9	63.8	62.0	53.2	44.0	36.3	32.4	24
The Dalles	32.3	37.8	45.7	53.2	60.1	66.3	72.2	71.2	62.7	53.2	42.3	35.2	60
Vale	26.5	31.7	41.1	49.5	56.6	64.1	71.5	69.1	59.6	48.5	37.2	28.2	26
Weston	31.8	34.4	41.4	49.0	54.8	61.1	69.1	68.4	59.2	50.0	40.9	33.9	30

PENNSYLVANIA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Erie	27.2	25.8	33.6	44.7	56.7	66.1	71.2	69.5	63.8	52.8	41.3	31.5	46
Franklin	26.5	24.6	35.7	46.3	58.0	65.6	70.5	68.3	62.3	51.3	39.6	29.2	25
Gettysburg	29.0	30.3	39.2	50.4	61.3	69.6	74.0	71.7	65.0	52.2	41.3	31.7	42
Harrisburg	29.9	29.0	39.1	51.5	62.1	70.0	74.7	72.7	66.0	54.4	43.0	33.0	33
Huntingdon	28.6	28.4	38.3	49.6	60.7	68.2	72.2	70.7	64.3	52.5	41.5	31.5	31
Lewisburg	25.4	25.8	35.3	48.2	58.5	67.2	71.5	68.9	62.0	50.2	39.1	29.0	45
Philadelphia	32.7	33.1	40.6	51.6	62.8	71.4	76.5	74.4	68.1	57.2	45.4	35.8	49
Pittsburgh	31.0	31.3	39.6	50.9	62.5	70.6	74.7	72.7	66.4	54.9	42.7	33.8	49
Reading	29.9	30.0	39.4	51.1	61.9	70.3	74.9	72.4	65.6	53.9	42.7	32.7	40
Scranton	27.2	25.5	36.2	47.9	59.5	66.7	72.1	69.2	63.0	52.2	40.6	30.0	25

SOUTH CAROLINA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Allendale	48.0	48.3	57.0	64.3	73.2	79.0	83.3	80.3	75.8	65.3	55.5	47.0	38
Camden	46.1	47.8	54.3	62.5	69.5	77.7	80.0	78.9	73.8	62.6	52.0	48.1	42
Charleston	49.3	51.7	57.2	63.8	72.4	78.5	81.3	80.3	76.2	67.1	58.1	51.3	38
Cheraw	43.7	45.0	53.4	61.5	70.7	77.2	79.9	78.6	73.1	62.1	52.2	43.8	39
Florence	45.3	46.1	55.4	62.6	72.2	78.4	81.2	80.2	74.6	64.1	53.9	44.9	39
Georgetown	48.8	49.1	57.5	63.5	72.2	78.4	80.5	80.4	75.6	66.3	56.1	48.9	28
Greenwood	42.9	43.5	52.7	61.6	70.9	77.4	79.6	78.4	73.1	62.2	52.0	43.0	37
Kingstree	47.7	47.5	56.6	63.2	71.8	78.0	80.6	79.5	74.3	64.5	54.7	47.3	39
Saint Matthews	46.4	46.7	56.1	63.2	71.8	77.8	80.2	79.5	74.2	62.7	54.7	46.3	39
Spartanburg	41.6	42.8	51.1	60.1	69.4	76.0	79.1	77.5	72.0	61.1	50.7	41.9	44
Winthrop College	43.5	43.4	53.3	60.8	70.1	76.1	79.1	78.4	72.6	62.4	51.7	43.0	21

SOUTH DAKOTA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Aberdeen	9.9	11.9	27.3	44.6	56.2	65.5	71.0	68.5	59.5	46.0	30.0	15.1	25
Academy	19.2	19.2	33.6	47.4	58.3	68.0	74.0	72.1	63.2	51.2	36.8	22.9	22
Brookings	12.7	14.6	29.5	44.5	55.7	64.8	70.1	68.4	59.7	47.3	31.8	17.7	25
Camp Crook	17.0	19.1	28.3	43.6	53.6	62.8	70.1	68.4	58.3	45.3	31.6	21.6	22
Cottonwood	18.4	19.1	34.7	46.8	55.5	67.8	74.5	71.0	61.7	48.0	34.5	20.9	11
Highmore	13.4	15.4	29.0	45.1	55.8	66.5	72.3	70.4	62.2	48.3	33.6	18.8	21
Huron	11.2	13.7	29.0	45.8	56.2	66.3	71.6	69.6	60.8	47.7	31.4	18.8	39
Milbank	10.7	12.7	27.8	43.6	55.5	64.6	70.1	68.1	59.6	47.2	31.1	17.1	25
Mitchell	16.0	16.9	31.7	46.4	57.7	66.9	72.1	69.8	61.5	49.4	34.4	20.7	25
Oelrichs	21.5	22.6	33.2	45.4	55.0	65.5	72.3	70.3	60.8	47.7	34.6	23.8	23
Ottumwa	16.0	17.7	31.2	44.7	54.0	67.0	72.8	69.6	60.4	47.5	33.6	20.0	12
Pierre	17.1	18.2	31.8	47.4	58.1	68.6	74.9	73.0	63.7	50.4	34.2	22.3	29
Pollock	7.6	12.2	27.6	44.4	54.2	65.0	70.9	68.3	58.6	44.9	30.2	15.0	11
Rapid City	22.8	22.5	32.1	45.2	53.7	64.1	70.9	69.6	60.7	48.4	36.0	27.7	33
Rosebud	22.8	22.1	32.5	47.0	56.8	66.5	73.4	71.0	61.1	49.0	36.4	24.0	20
Sioux Falls	15.1	16.5	31.3	46.2	58.0	67.2	72.3	70.5	61.9	49.4	33.5	19.7	25
Vale	18.7	21.0	33.0	46.2	54.2	65.1	71.7	68.8	59.9	46.8	34.2	21.7	13
Yankton	16.9	19.8	32.4	47.9	59.4	68.9	74.1	72.2	63.4	51.0	34.9	22.9	48

TENNESSEE

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Carthage	38.4	40.4	49.7	58.9	67.4	75.1	77.6	76.9	71.6	60.1	48.7	40.0	37
Chattanooga	41.4	43.5	51.6	60.2	68.6	75.6	78.2	77.4	72.1	61.6	50.8	42.6	42
Johnson City	37.1	38.3	47.8	55.4	65.2	72.0	75.0	73.9	68.6	57.7	45.8	37.9	25
Johnsonville	39.6	40.1	51.3	59.2	68.4	75.5	78.9	78.3	72.3	60.8	49.3	39.9	25
Knoxville	38.7	41.2	49.0	58.0	66.9	74.0	77.0	75.9	70.4	59.1	47.7	39.8	50
Memphis	41.0	43.6	52.6	61.8	70.4	78.0	80.8	79.6	73.4	63.0	51.6	43.6	50
Nashville	38.8	40.9	49.6	59.0	68.2	76.0	79.1	78.0	71.7	60.6	48.9	41.0	50
Rugby	36.2	36.9	46.4	54.8	64.1	71.2	74.1	73.0	67.4	55.7	45.0	37.3	33
Savannah	40.7	42.6	51.9	60.5	68.8	75.9	79.0	78.5	72.3	61.0	50.2	42.1	34
Trenton	38.3	40.4	49.8	59.6	67.6	75.0	78.1	77.4	71.3	59.7	48.3	39.6	38
Tullahoma	38.6	39.7	49.6	57.8	66.1	73.1	76.3	75.6	70.2	58.7	47.4	40.0	32

TEXAS

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Abilene	44.5	46.8	56.2	64.3	71.8	79.2	82.6	82.0	75.4	65.2	53.9	45.9	35
Alice	56.2	58.2	64.5	71.1	77.4	82.7	84.6	85.7	81.2	73.4	64.0	57.3	11
Amarillo	36.4	35.4	47.0	55.2	65.6	72.7	74.9	75.4	66.2	57.6	46.4	36.6	29
Big Spring	45.7	48.2	57.1	64.4	73.1	81.0	83.2	83.1	76.2	65.2	53.6	44.2	19
Blanco	48.8	49.0	57.5	63.7	71.8	79.5	82.7	82.8	77.1	66.9	56.6	48.4	22
Brenham	51.4	53.7	62.2	68.4	74.9	81.3	83.9	83.9	79.1	69.9	60.7	42.3	37
Brownsville	59.4	62.9	68.3	73.7	78.6	82.4	83.8	83.9	80.5	74.6	67.5	61.5	60
Brownwood	46.8	48.4	56.7	65.1	72.4	80.7	83.9	83.7	76.9	65.8	54.1	46.3	27
Childress	39.9	42.6	53.0	61.8	69.0	78.0	81.8	80.8	74.5	63.4	49.7	43.6	14
Claytonville	44.3	46.5	54.3	63.6	71.2	78.8	81.7	81.1	75.4	65.3	53.1	44.3	23
Corpus Christi	56.2	58.1	64.4	70.5	75.8	80.5	82.0	82.3	79.7	73.1	64.6	57.7	34
Dalhart	33.4	35.4	45.3	52.3	61.8	71.8	76.6	74.6	68.0	55.2	43.2	32.0	13
Dallas	45.1	47.4	56.4	64.7	72.7	80.7	84.0	83.3	77.3	66.2	54.9	46.7	44
Del Rio	52.4	55.6	63.7	69.5	76.6	82.8	84.5	84.6	79.5	69.5	59.1	51.1	15
El Paso	44.7	49.5	55.9	63.5	71.9	80.3	81.6	79.6	73.9	63.7	52.3	45.1	41
Encinal	55.9	58.8	65.1	72.0	79.9	85.2	86.6	86.8	81.6	73.4	63.6	54.8	10
Falfurrias	59.1	61.7	67.9	73.7	78.7	83.5	85.3	85.9	81.8	74.4	66.0	58.6	14
Fort McKavett	44.4	50.5	58.1	65.4	72.7	78.4	81.5	80.4	74.5	65.7	53.7	46.8	23
Fort Stockton	46.5	50.5	57.9	64.7	73.5	79.9	81.2	79.8	73.9	64.9	54.1	46.4	33
Galveston	53.6	55.9	62.5	69.2	75.5	81.3	83.4	83.2	79.9	72.5	63.0	56.3	49
Graham	44.1	46.3	58.0	65.5	73.1	80.9	84.6	83.7	77.2	65.8	53.8	45.9	22
Hallettsville	53.7	55.0	63.4	69.8	76.3	82.2	84.6	84.4	79.9	70.9	61.9	54.1	29
Haskell	43.4	45.3	55.0	64.2	72.0	80.8	84.4	83.6	76.8	65.3	53.3	44.2	26
Houston	53.2	55.1	62.9	69.3	75.1	81.1	83.3	82.9	78.8	70.4	61.2	54.2	32
Huntsville	49.3	51.0	59.8	67.3	74.0	80.8	83.5	83.0	77.6	68.2	58.7	50.9	38
Lampasas	47.6	49.0	58.5	65.1	72.4	79.7	83.0	83.1	76.8	66.5	56.1	48.3	29
Liberty	55.0	55.8	62.5	68.0	74.0	80.9	83.0	82.7	79.1	69.5	61.4	53.8	16
Longview	47.4	49.4	57.8	65.1	73.7	81.3	83.9	81.1	77.2	66.3	56.1	48.0	37
Mexia	47.1	48.9	58.3	64.7	71.8	80.1	83.5	83.4	78.2	66.9	57.1	47.5	16
Miami	38.0	40.7	49.7	57.9	66.6	76.0	80.3	78.8	72.2	59.2	47.9	37.0	15
Midland	42.5	47.2	54.8	64.5	72.2	78.3	81.6	79.5	73.9	64.3	52.6	43.3	14
Nacogdoches	47.9	50.9	59.0	64.7	71.8	79.0	81.5	81.7	76.6	66.4	57.3	48.0	21
O2 Ranch	47.2	52.3	55.6	63.2	72.3	78.3	79.5	76.9	71.9	64.5	53.9	47.0	7
Palestine	47.9	50.9	59.0	65.9	72.2	79.4	82.0	81.8	76.9	67.4	57.6	50.4	39
Pierce	54.5	54.7	62.0	67.3	73.7	79.5	81.8	82.4	77.9	69.8	61.8	54.2	15
Plainview	41.0	42.2	51.0	59.0	67.6	74.8	77.3	76.8	70.6	60.6	50.2	40.6	25
San Antonio	42.7	55.2	62.6	69.1	75.0	81.1	83.5	83.6	79.0	70.3	60.8	53.8	36
Sherman	43.6	46.6	55.5	63.8	71.6	79.6	82.8	82.2	76.1	65.6	54.1	45.8	33
Taylor	49.4	51.2	60.4	66.4	73.2	80.4	82.9	83.0	78.0	68.1	58.8	49.6	19
Uvalde	53.1	56.6	64.5	70.1	76.6	82.6	84.9	84.1	79.1	71.1	60.3	52.9	17
Victoria	55.9	57.1	64.7	70.6	76.2	81.9	84.1	84.4	80.4	72.5	63.8	55.8	21
Weatherford	43.9	45.5	55.9	64.0	71.5	79.8	83.8	82.4	76.1	65.4	54.7	45.2	32

UTAH

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Castle Dale	19.3	25.8	37.8	45.9	53.9	63.8	69.3	68.1	58.9	47.8	36.8	23.1	19
Fort Duchesne	13.0	19.3	36.0	47.8	55.7	64.8	71.0	69.3	60.5	46.8	33.7	17.5	29
Hite	35.7	42.4	51.1	59.2	68.2	77.7	84.2	82.8	72.5	59.7	47.5	35.2	14
Kelton	22.5	28.1	39.2	48.3	57.4	68.0	75.6	73.0	60.2	47.5	34.3	26.3	39
Loa	24.6	24.1	32.2	40.6	48.7	58.6	65.9	62.9	53.0	41.3	31.1	20.9	18
Logan	24.3	26.7	36.2	47.5	54.4	63.4	71.7	70.7	61.2	49.9	37.7	25.7	27
Moab	28.8	36.2	43.4	55.2	63.6	72.1	77.7	75.3	66.3	53.6	41.4	30.3	28
Parowan	29.0	31.9	39.4	47.1	54.6	64.3	70.5	66.6	60.2	49.4	40.6	28.8	28
Salt Lake City	29.2	33.3	41.7	49.9	57.4	67.1	75.6	74.5	64.4	52.5	40.9	32.1	45
Scipio	27.2	31.1	38.7	46.6	53.1	62.9	69.2	68.3	59.3	47.9	37.5	26.6	24

VERMONT

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Burlington	18.9	18.8	29.9	43.2	56.2	64.9	70.0	67.6	60.2	49.5	36.3	23.5	35
Enosburg Falls	15.2	15.0	26.8	41.5	54.1	62.2	68.1	64.9	57.8	47.5	33.6	18.9	20
Northfield	15.2	15.7	26.2	39.8	52.4	60.9	65.7	62.8	55.8	45.2	32.7	20.0	34
Wells	18.3	17.1	28.8	41.6	54.5	62.8	68.6	65.6	58.7	47.2	33.8	21.3	20

VIRGINIA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Callaville	39.0	38.3	48.5	56.4	66.0	72.9	76.9	76.0	69.9	59.6	48.6	40.0	29
Charlottesville	36.2	35.2	46.1	55.7	66.3	72.3	76.2	74.7	65.5	58.3	46.0	37.5	25
Lynchburg	37.2	38.5	46.4	55.8	65.8	73.4	77.2	75.4	69.1	57.9	46.9	39.2	48
Norfolk	41.2	41.8	48.2	56.8	66.5	74.4	78.6	77.3	71.8	61.8	51.3	42.9	50
Richmond	38.4	39.9	47.2	57.0	67.2	74.5	78.1	76.8	70.9	59.9	48.9	40.3	40
Wytheville	34.4	34.1	43.6	51.1	60.8	67.4	70.9	70.0	64.2	53.9	42.7	34.0	17

WASHINGTON

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Aberdeen	39.1	41.0	44.1	47.9	52.2	56.3	59.7	60.5	57.4	52.0	45.2	40.4	30
Blaine	35.8	38.2	41.7	47.2	52.6	57.7	61.0	60.1	55.0	48.6	42.1	38.0	23
Centralia	38.4	40.7	44.4	49.2	54.2	59.1	63.7	63.6	58.2	51.8	45.1	39.9	28
Moxee	28.2	33.9	42.7	50.4	57.7	64.4	70.9	69.5	60.0	49.6	38.9	30.6	30
North Head	41.6	42.8	44.9	47.8	51.4	54.7	57.5	58.0	56.5	53.2	48.0	43.9	34
Odessa	26.7	32.4	41.4	49.0	56.1	63.3	71.1	69.1	59.8	49.3	38.1	29.1	18
Republic	22.6	25.9	36.8	45.7	51.5	57.8	64.4	63.0	54.6	43.8	32.8	24.4	17
Seattle	40.0	41.7	44.9	49.5	54.7	59.4	63.7	63.6	58.6	52.0	46.0	41.9	31
Spokane	27.2	31.0	39.9	48.2	55.8	62.3	69.5	68.4	58.6	48.4	37.7	30.9	41
Totoosh Island	41.1	41.8	43.6	46.6	50.1	53.2	55.3	55.4	53.9	50.8	46.5	43.4	33
Walla Walla	33.1	37.2	45.7	52.9	59.5	66.0	74.5	73.7	64.0	54.3	43.3	36.1	36
Waterville	20.7	25.5	34.6	44.8	52.8	59.5	66.8	66.6	56.9	46.4	33.2	24.4	28

WEST VIRGINIA

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Elkins	31.2	29.6	40.4	48.3	59.3	66.0	70.0	69.1	62.9	52.8	40.3	31.6	22
Glenville	33.1	32.7	44.3	53.4	63.5	70.8	74.9	73.9	67.7	56.0	43.6	35.0	28
Huntington	32.8	32.6	44.6	54.0	64.9	72.6	76.4	74.8	68.2	56.2	43.6	34.4	27
Parkersburg	32.9	32.6	43.1	53.0	63.5	71.5	75.1	73.7	67.7	55.9	44.0	35.1	32
Powellton	36.8	35.4	45.7	54.5	63.9	70.7	74.2	72.9	67.1	55.9	44.7	36.5	25
Terra Alta	27.8	27.8	39.0	47.2	59.0	65.8	69.1	67.9	62.3	51.9	41.5	30.0	27
Union	32.6	33.1	43.0	50.6	60.8	67.0	71.0	70.6	65.1	54.1	41.0	31.9	17

WISCONSIN

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Barron	9.4	11.5	26.2	42.7	53.4	63.6	68.3	64.9	57.9	45.0	30.0	16.3	29
Eau Claire	12.6	14.7	29.7	45.9	57.2	66.7	71.1	68.8	60.8	48.8	32.6	18.9	30
Green Bay	15.4	16.5	28.7	45.0	54.6	65.3	70.1	67.6	60.6	48.7	34.3	22.3	34
Hayward	9.1	10.7	25.0	42.1	53.1	63.3	67.4	64.4	57.3	45.4	29.7	16.2	31
La Crosse	15.5	19.8	31.7	47.4	59.1	68.2	72.8	70.1	61.8	50.1	34.7	22.7	48
Madison	16.6	18.6	31.0	45.6	57.4	67.1	72.1	69.7	62.1	50.2	35.3	22.4	42
Medford	12.1	13.5	26.9	42.5	53.9	64.6	68.6	66.3	58.8	46.1	30.4	17.9	30
Milwaukee	20.4	22.1	32.0	43.4	53.7	63.7	70.0	69.0	62.2	50.5	36.8	25.6	50
Minocqua	9.5	10.9	24.4	38.8	52.0	63.0	67.4	64.1	57.3	45.1	30.5	16.2	17
Prairie du Chien	17.2	19.4	33.2	48.2	59.8	69.0	73.7	70.8	63.4	51.9	36.4	23.2	33
Waupaca	15.2	15.6	29.6	44.4	56.2	65.7	71.0	67.9	60.4	48.6	33.7	20.1	24

WYOMING

Stations	January	February	March	April	May	June	July	August	September	October	November	December	Length of record (years)
Bedford	17.4	19.3	27.6	37.2	46.0	53.2	59.8	58.6	50.8	40.3	29.9	17.6	20
Cheyenne	25.8	26.6	32.9	41.0	50.6	60.8	66.8	65.6	57.0	45.5	35.0	28.1	48
Dubois	20.6	22.4	28.6	37.0	44.0	52.8	58.8	56.8	48.7	40.0	30.8	21.6	13
Ervay	21.2	22.2	29.6	38.2	47.0	58.2	65.0	63.4	54.0	42.4	32.3	21.6	12
Evanston	20.0	21.0	28.4	38.7	45.9	54.5	61.8	60.5	52.2	41.2	31.1	19.8	23
Fort Laramie	26.0	25.5	35.1	45.5	54.6	64.9	71.6	70.6	60.8	47.4	36.0	26.4	26
Green River	18.6	22.2	33.0	42.2	50.8	60.4	68.2	66.2	56.2	43.1	32.0	18.8	16
Hyattville	22.9	25.4	35.2	45.8	54.2	63.8	70.2	68.2	58.5	46.8	35.9	25.0	21
Lander	19.6	21.7	31.9	42.2	50.7	60.2	66.9	65.4	55.7	43.7	31.2	19.4	29
Laramie	22.2	22.6	29.8	37.6	46.6	56.6	62.9	61.3	53.5	42.0	32.2	21.8	29
Lusk	23.2	23.2	31.8	42.2	51.6	61.5	67.8	66.4	56.6	44.2	33.2	24.3	27
Pathfinder	24.7	24.4	33.3	43.0	52.2	62.8	70.2	68.6	58.7	46.2	35.8	24.3	21
Pine Ridge	17.4	19.8	30.1	43.8	50.3	62.2	69.8	68.8	57.8	46.6	34.5	21.8	15
Rawlins	22.2	23.2	30.8	41.4	50.0	60.4	67.6	65.2	55.2	43.8	33.0	22.1	19
Sheridan	18.9	22.4	32.7	43.4	50.7	61.1	67.3	65.4	56.3	43.7	32.8	22.1	25
Shoshone Dam	26.4	29.0	35.3	44.0	50.8	61.1	68.6	67.5	58.8	48.2	38.8	28.6	15
Yellowstone Park	18.0	19.7	27.0	37.3	45.5	53.9	61.3	60.2	51.4	40.4	29.2	20.7	34

SUNSHINE AND WIND

Source of data.—The sunshine data collected by the Weather Bureau are not entirely satisfactory, because the automatic instruments in use up to the present time do not indicate with sufficient accuracy the different degrees of sunshine intensity. The electrical thermometric recorder is used by the Weather Bureau. This instrument consists essentially of a straight glass tube with a cylindrical bulb at each end, the lower bulb, as exposed for service, being coated on the outside with lampblack. The whole is inclosed in a protecting glass sheath, the space between the inner tube and the protecting sheath being exhausted of air and hermetically sealed. Mercury is used to separate the air in the bulbs, and two platinum wires are inserted into the inner tube about midway between the bulbs, but above the point the top of the mercury column assumes in the absence of sunshine. The ends of the wires within the inner tube are slightly separated, but are so arranged that the electric circuit will be closed by the mercury coming in contact with them. The instrument operates by the expansion of the air in the lower blackened bulb and of the mercury in the tube, when exposed to the heat of sunshine, causing the top of the mercury column to move upward in the tube until it comes in contact with the end of the wires and thus closes the circuit. By this method the record is automatically maintained until in the absence of sunshine the mercury in the tube recedes below the inserted wires, when the circuit is broken.

The instrument is not delicate enough to record sunshine in the early morning immediately after the sun appears above the horizon, and likewise the sun's rays usually become too weak to maintain a record a short time before sunset. In such cases the actual unrecorded sunshine is noted by personal observation, and the records are corrected by adding thereto, when the sun is shining, the interval between the time of actual sunrise and the beginning of the automatic record, and between the ending of the record and the time of actual sunset.

These instruments are located at the first-order stations of the Weather Bureau only, and their records constitute the sole source of data used in the preparation of the several charts.

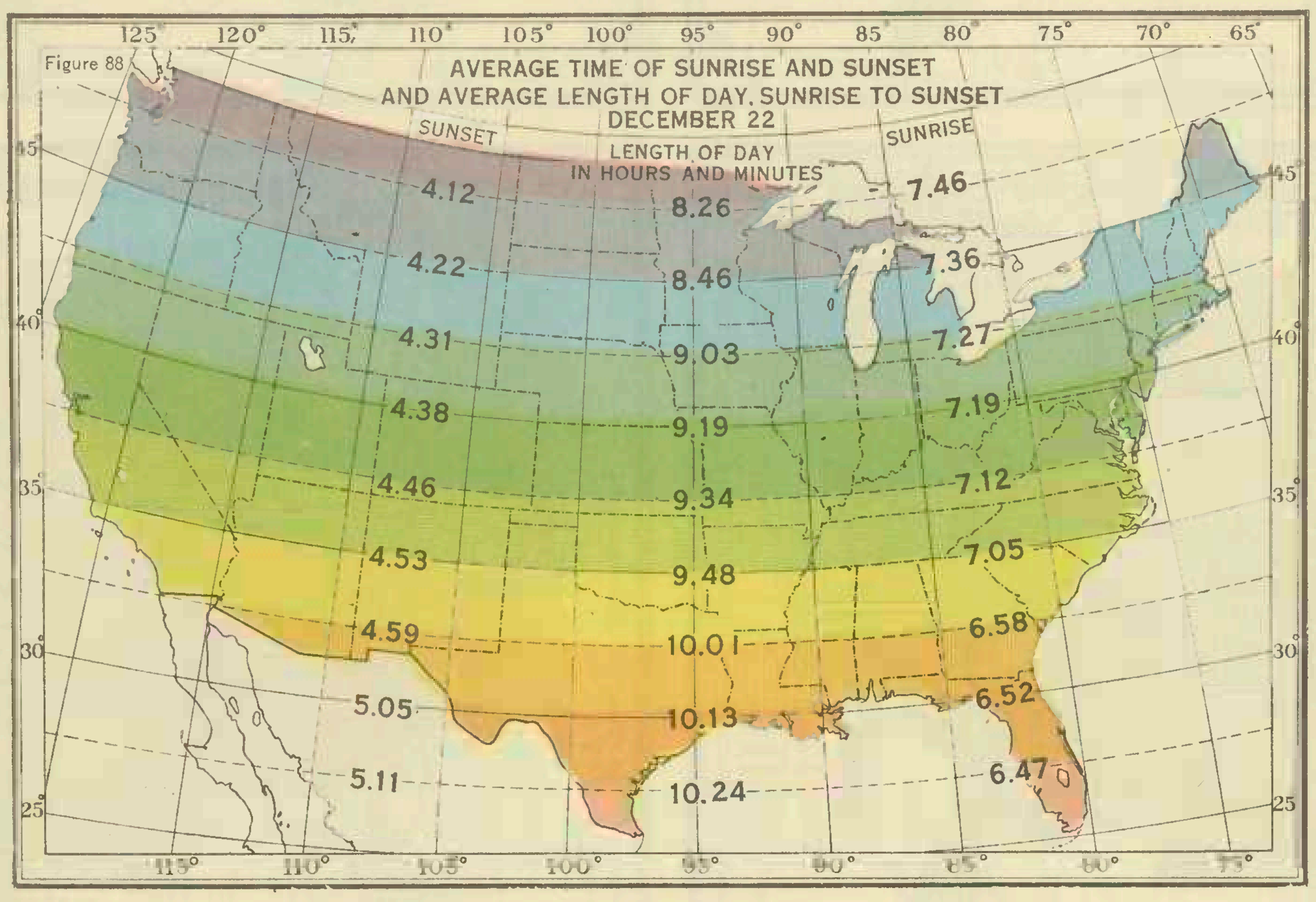


Figure 88 shows for each two and one-half degrees of latitude the average time of sunrise and sunset, mean solar time, and also the average length of the day, sunrise to sunset, on December 22, the winter solstice, and the shortest day of the year. The length of the day from sunrise to sunset, corresponding to the possible amount of daily sunshine, varies on December 22 from 10 hours and 35 minutes at latitude 25° N., the latitude of the southern end of Florida, to 8 hours and 10 minutes at latitude 49° N., the northern boundary of the United States from Minnesota westward. It decreases with increasing latitude until north of the Arctic Circle the sun does not rise above the horizon

Length of day and possible sunshine.—Sunshine data are usually expressed as the actual number of hours of daily sunshine or in percentage of the possible amount. Figures 88 and 89 show for the United States the possible amount of sunshine or length of the day from sunrise to sunset, for each two and one-half degrees of latitude, on December 22 and June 21, the winter and summer solstices, respectively, and the shortest and longest days of the year. At the time of the equinoxes, about March 21 and September 22, the length of the day, or total possible sunshine, is substantially 12 hours in all portions of the world.

The variation in the length of the day from winter to summer increases with latitude. In the extreme southern portion of the United States the days during the latter part of June, or the longest of the year, are only about three and one-half hours longer than during the latter part of December, the shortest days; but in the extreme northern portion of the country the difference is nearly eight hours. On clear days in early summer the extreme Northern States receive about two hours more sunshine than that received in the Florida Peninsula and extreme southern Texas, but in early winter the reverse is true.

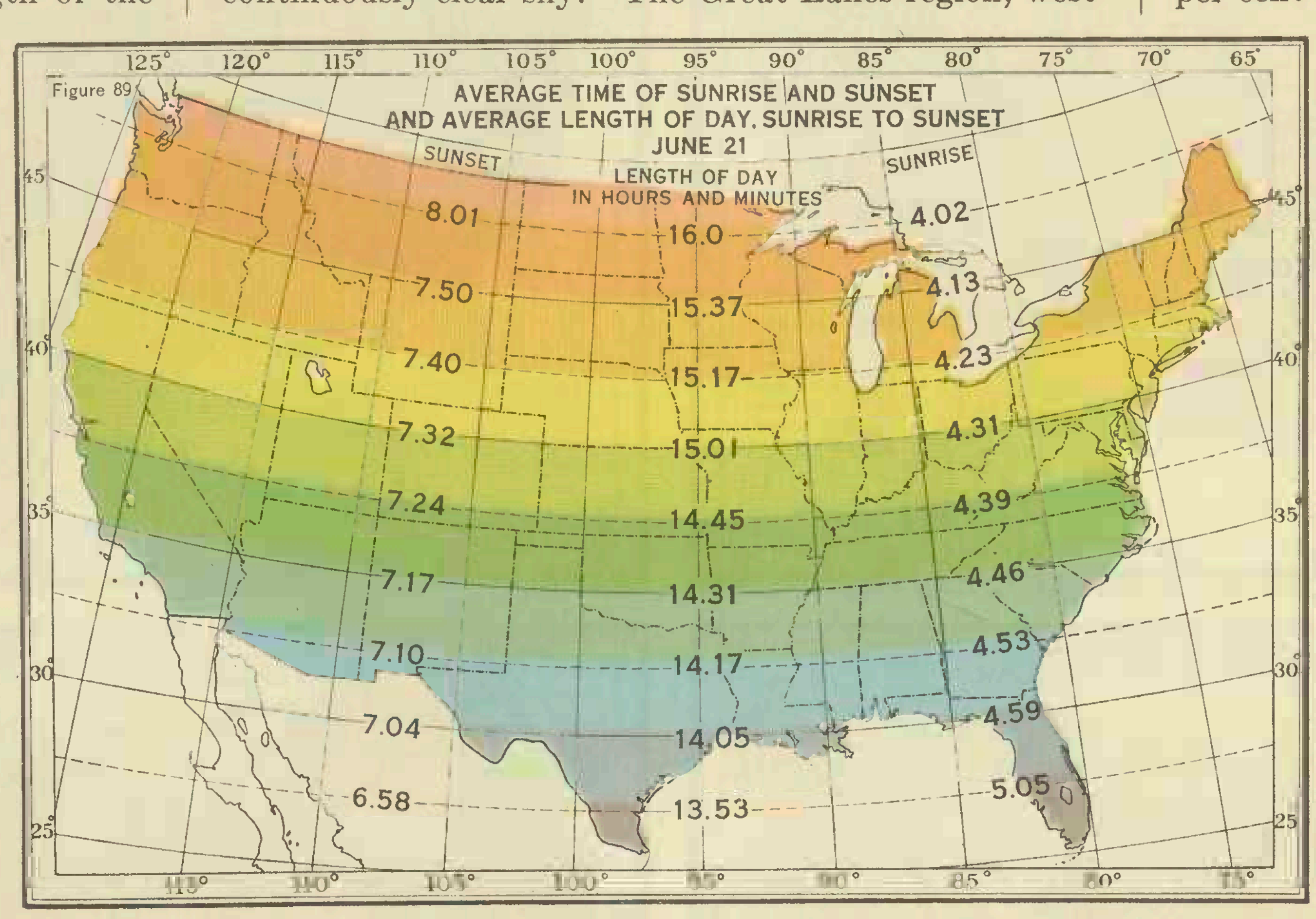


Figure 89 shows for each two and one-half degrees of latitude the average time of sunrise and sunset, mean solar time, and also the average length of the day, sunrise to sunset, on June 21, the time of the summer solstice, and the longest day of the year. The length of the day from sunrise to sunset, corresponding to the possible amount of daily sunshine, varies on June 21 from 13 hours and 41 minutes at latitude 25° N. to 16 hours and 19 minutes at latitude 49° N., increasing with the latitude until north of the Arctic Circle the sun on this day does not set and the day is 24 hours long

Geographic variations in annual sunshine percentage.—For the year as a whole the least relative amount of sunshine in the United States is received along the north Pacific coast, where the averages are only about 40 per cent of the total hours from sunrise to sunset, and in portions of the Great Lakes region and the central and northern Appalachian Mountain districts, where somewhat less than 50 per cent of the possible amount is received. In the remaining districts east of the Mississippi River and in the northern border States from the Great Lakes westward to the Rockies the average annual sunshine ranges between 50 and 60 per cent of the possible amount, except in portions of the Southeastern States, where it is somewhat higher, especially in the Florida Peninsula. Between the Mississippi River and the Rocky Mountains the annual percentage is mostly between 60 and 70, which is true also of the central portion of the Rocky Mountain and interior Plateau regions. The maximum amount of sunshine in the United States occurs in the far Southwest, including extreme western Texas, and portions of New Mexico, Arizona, and California. In southwestern Arizona and the adjoining portion of California the sun shines on the average for the year in nearly 90 per cent of the total number of hours from sunrise to sunset.

Seasonal variations in amount of sunshine.—Figures 90 to 101, inclusive, show for the different sections of the United States, and for each month of the year, the average number of hours of daily sunshine, from which the seasonal distribution of this important climatic factor may be seen. Figures 102 to 105, inclusive, show for the four seasons, winter, spring, summer, and fall, the average percentage received of the total possible amount of sunshine.

Because of the fewer hours of daylight and the greater amount of cloudy weather in winter the amount of sunshine is usually much less than in summer. Not only are there fewer actual hours of sunshine in winter, but the percentage of the possible amount is much less than in summer. This is due to the fact that in winter cyclonic action is more pronounced, and several successive days of cloudy weather may be experienced in the passing of a cyclonic storm, whereas in summer cloudy weather and rainfall are usually of a more local character and fewer entirely overcast days are experienced. During the winter months more than half of the United States, including nearly all districts from the Mississippi Valley eastward and the central and northern districts west of the Rocky Mountains, receive less than half the amount of sunshine that would be received with continuously clear sky. The Great Lakes region, western Montana, northern Idaho, and western Washington receive the least sunshine in winter, the average amount in some of these localities being less than two hours daily, or about one-fourth of that possible. In extreme western Texas, most of New Mexico and Arizona, and in southeastern California the winters are sunny, these districts receiving on the average nearly eight hours of sunshine daily.

With the advent of spring the amount of sunshine increases rapidly, especially in the more northern districts. In portions of the upper Lakes region and of the far Northwest, where in December and January the average daily sunshine is only about two hours, in April it is more than seven hours. The regions of least sunshine during the spring months are along the north Pacific coast, where only about 40 per cent of the possible amount is received, and in the upper Ohio Valley and the northern Appalachian Mountain districts, where somewhat less than half the possible amount occurs. The maximum amount of sunshine during this season is received in the lower Colorado River Valley, where the average for the three spring months is 12 hours a day, or about 90 per cent of the possible amount. Over most of the Great Plains region the average sunshine in spring ranges between 60 and 70 per cent of the possible amount but in most districts to the eastward it is from 5 to 10 per cent less than this.

The increase in the amount of sunshine from winter to summer in the northern portion of the United States is very pronounced. In most of the northern border States there are, on the average, in July, about six and one-half hours more of sunshine daily than in January. In the South the increases are not so large, the daily July excess over January in the central and east Gulf States being only about two and one-half hours. East of the Rocky Mountains the distribution of sunshine in summer is the reverse of winter, as the northern districts receive more than the southern. In much of the central and northern Great Plains there is usually received in July from 40 to 50 per cent more sunshine than occurs along the central and eastern Gulf coast. The minimum amount of sunshine in summer occurs along the central and northern Pacific coast, where at some places only about 40 per cent of the possible amount is received, and along the Gulf, the central and northern Atlantic coasts, and in the Appalachian Mountain districts, where the average amounts are somewhat less than 60 per cent of the possible. The maximum amount of sunshine in summer occurs in the Great Valley of California and over the western portion of the interior Plateau region. The interior of California experiences practically cloudless skies during the summer months, the average daily amount of sunshine in most of the Great Valley being nearly 14 hours, or about 95 per cent of the possible.

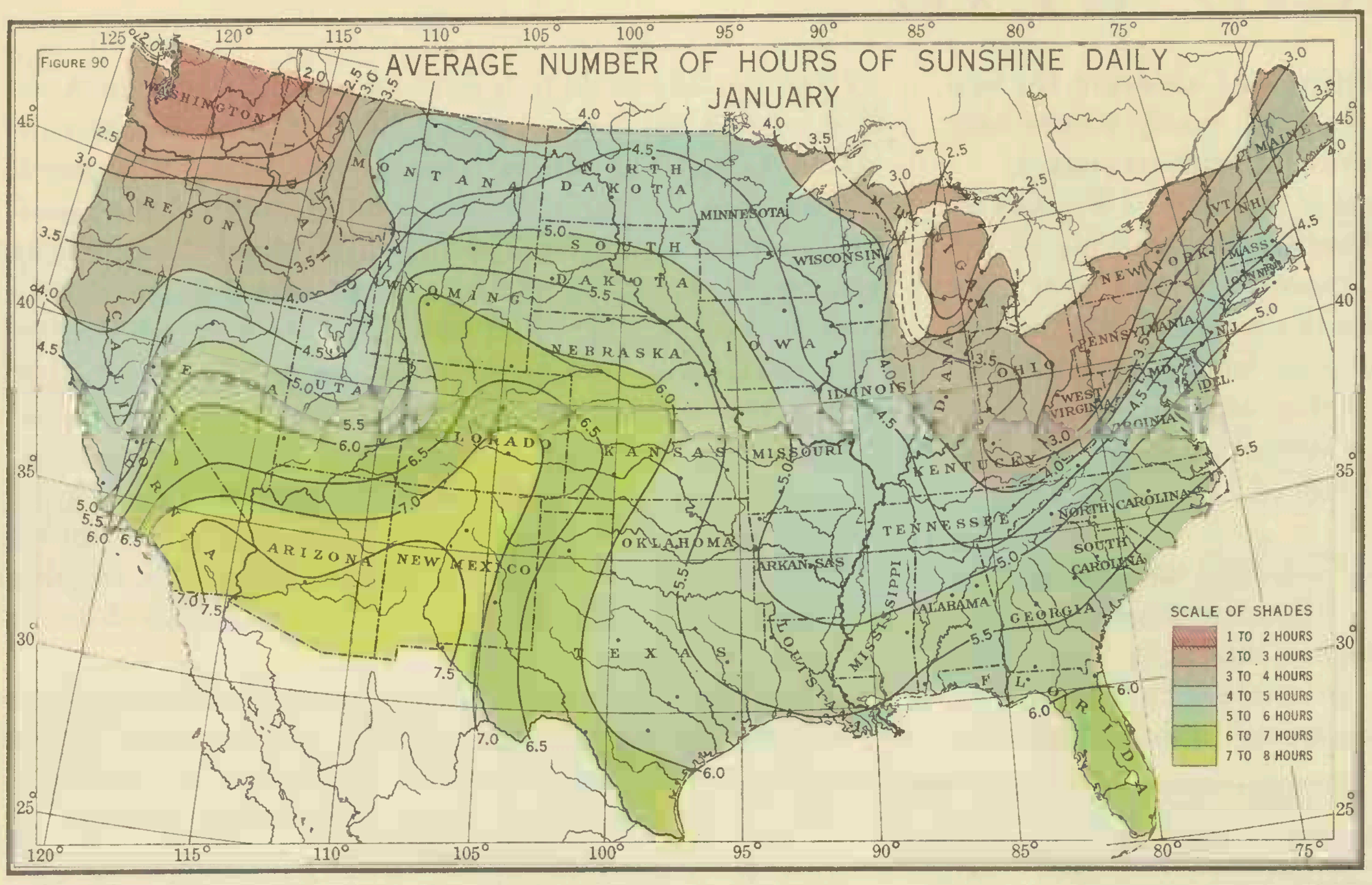
In fall, especially during October and November, much cloudy weather is experienced in the region of the Great Lakes, the upper Ohio Valley, and in the far Northwest. In western Washington the average daily amount of sunshine in November is less than two hours. The largest amount in fall occurs in the lower Colorado River Valley, where the daily average is over nine hours. In most of the important agricultural districts of the country the fall sunshine averages between 55 and 65 per cent of the possible amount.

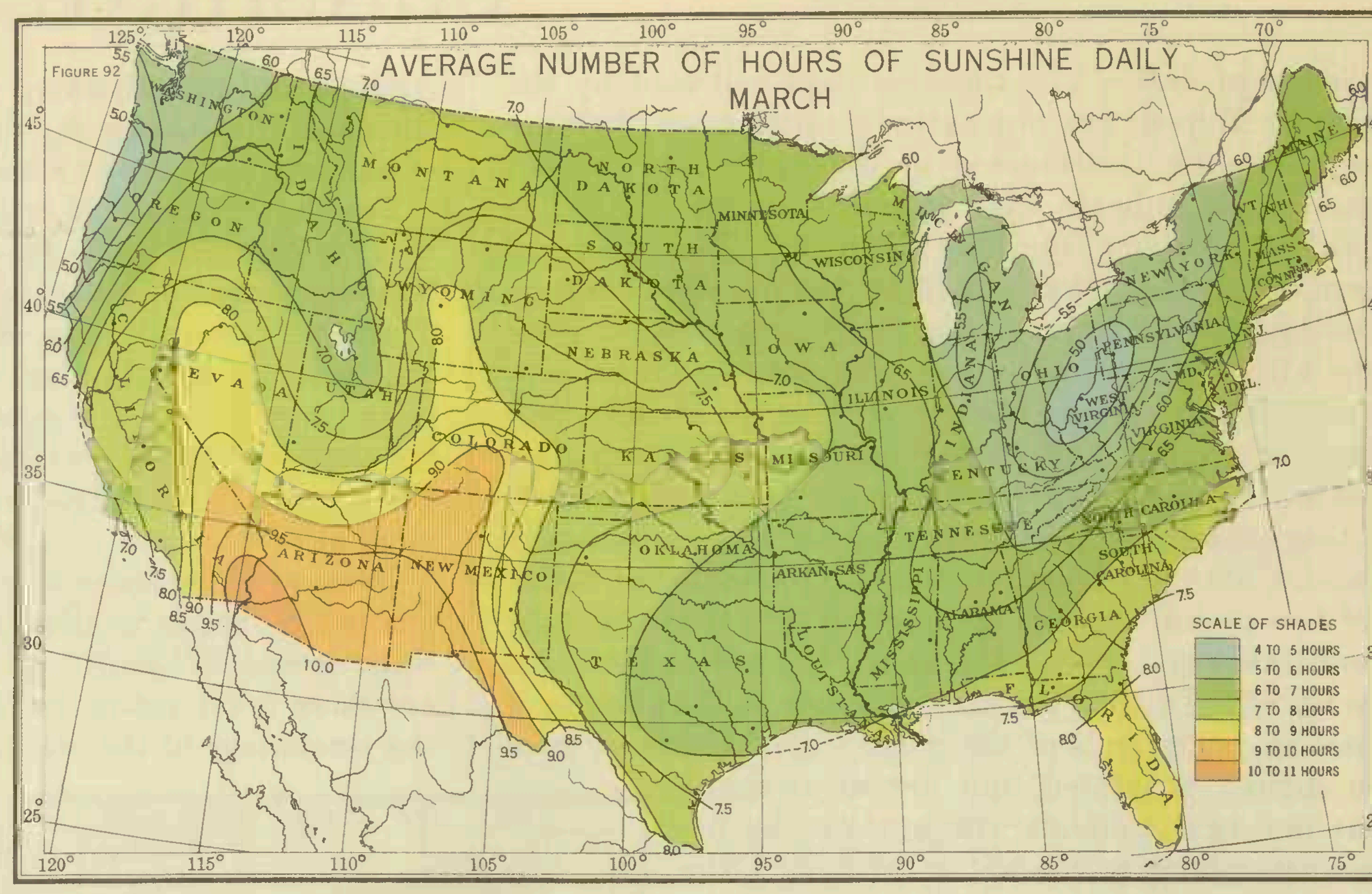
WIND

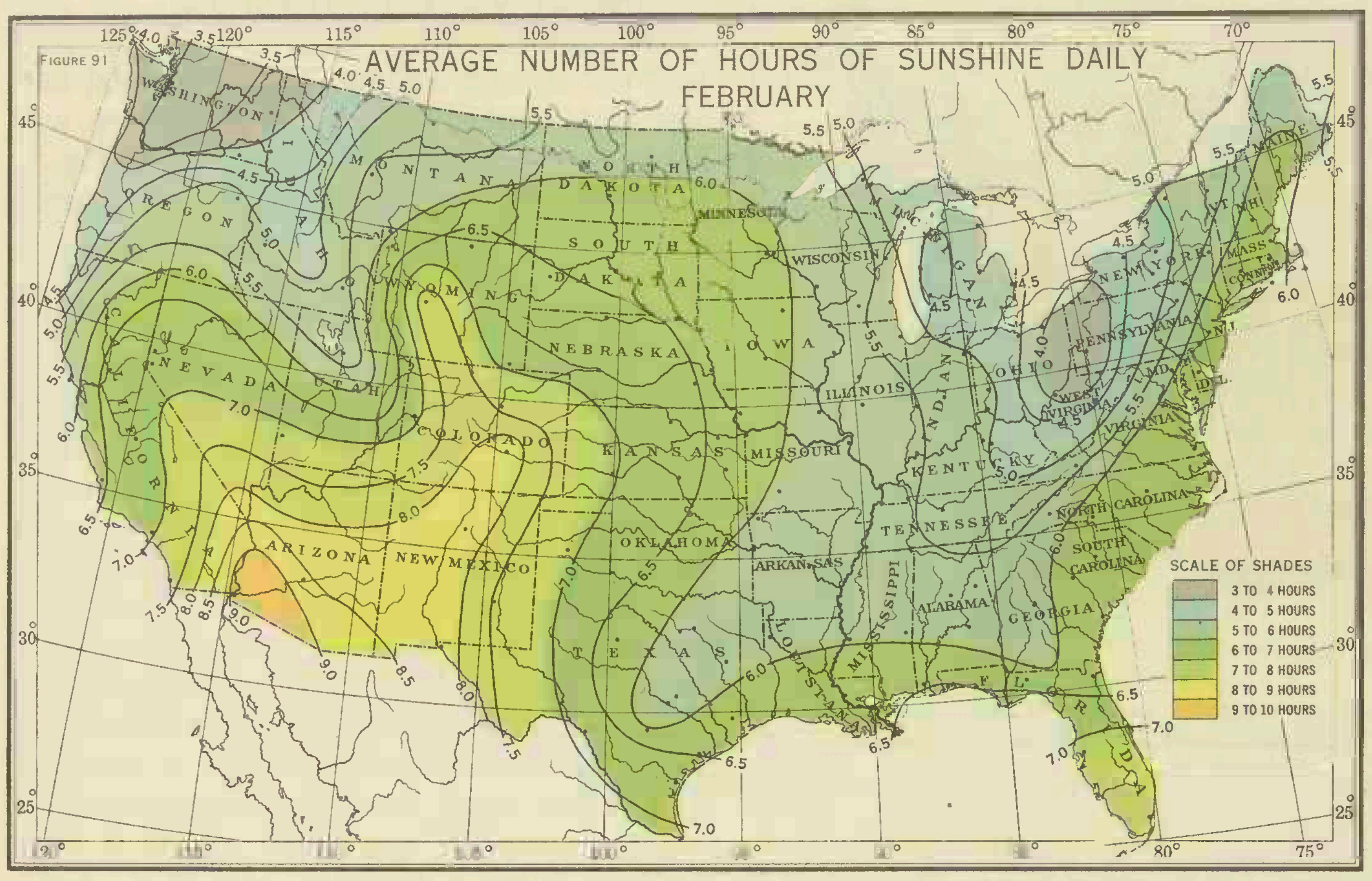
Importance of wind as a climatic factor.—The most important function of wind is the transportation of moisture from the oceans and other large bodies of water to the land, where it is condensed and precipitated in some form of water, for the sustenance of plant and animal life. The surface drift of the wind has also a marked influence on the temperature of many places, especially in localities to the leeward of large bodies of water. The on-shore drift of the wind gives to the Pacific coast region of the United States comparatively warm and equable winters and cool summers. This influence is also felt, but to a much less extent, on the leeward side of the Great Lakes and likewise is in evidence to some extent along the shores of smaller bodies of water.

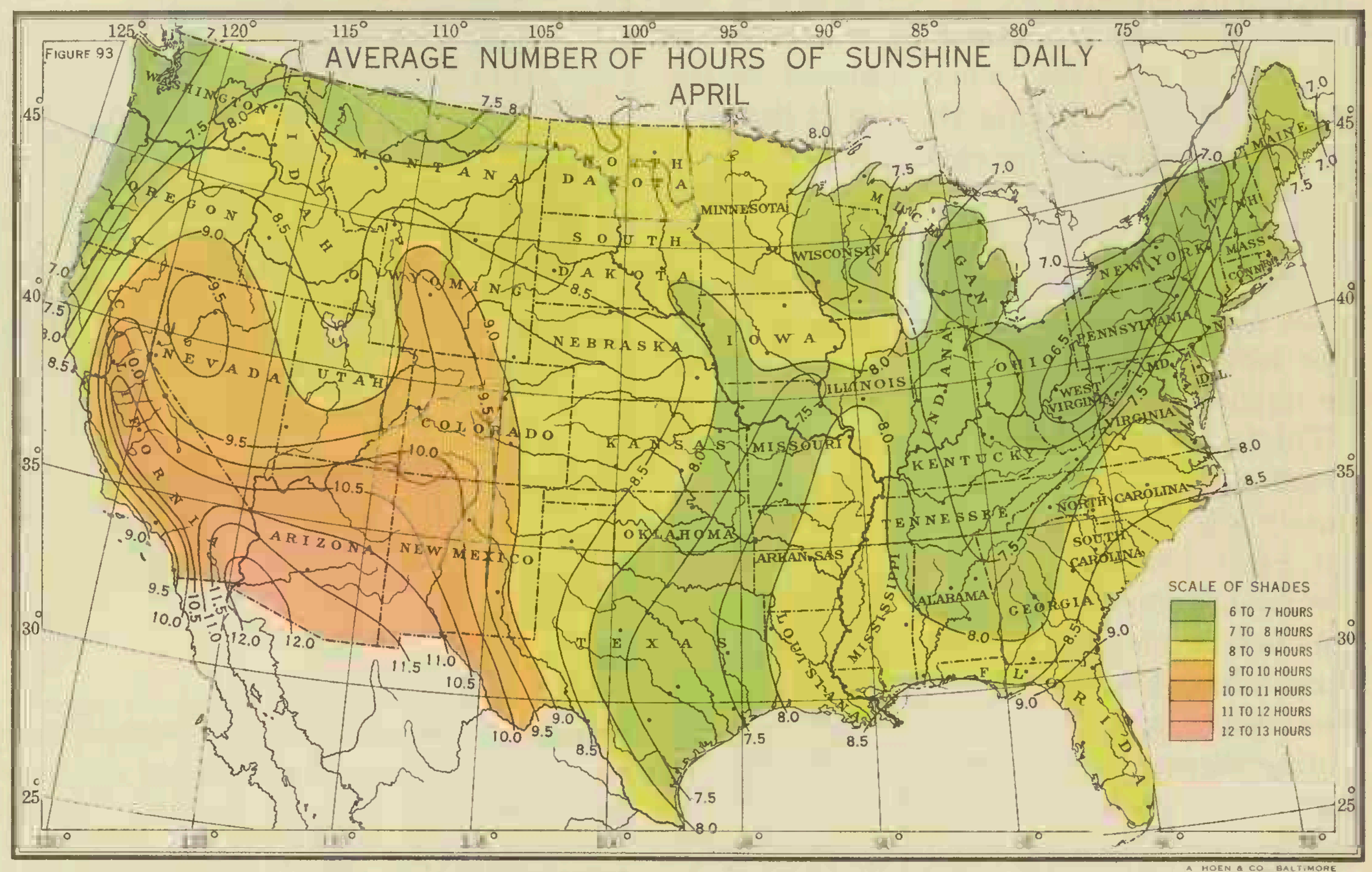
In addition to these climatic functions, air movements have an important physiological aspect. They produce a cooling tendency in all conditions of temperature, by accelerating the conduction of heat from the body and by increasing the opportunity for evaporation, which is a cooling process. The physical effects of high temperatures are very much modified when accompanied by brisk air movement. But a low temperature which may be even stimulating in a calm becomes unpleasant in windy weather.

Source of data.—There are two important aspects of air movement which should be considered in studying the relation of wind to climate, namely, velocity and direction. The average hourly velocities of the wind for the year as a whole in the different portions of the United States are shown in Figure 106, and the average velocities at 3 p. m. local standard time, the approximate hour of greatest wind movement, in Figure 107. These charts are based on anemometer records for the 20-year period 1891 to

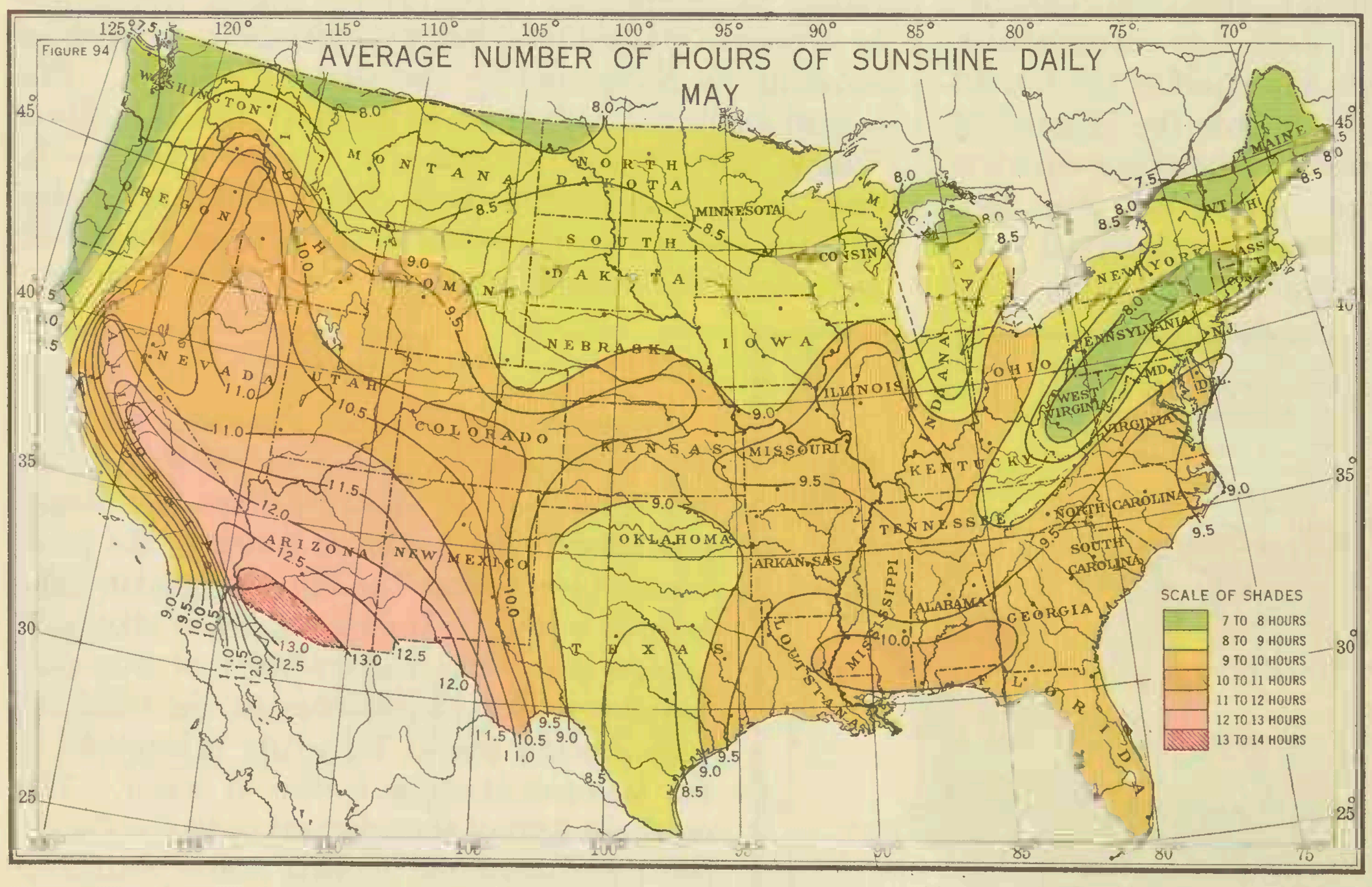


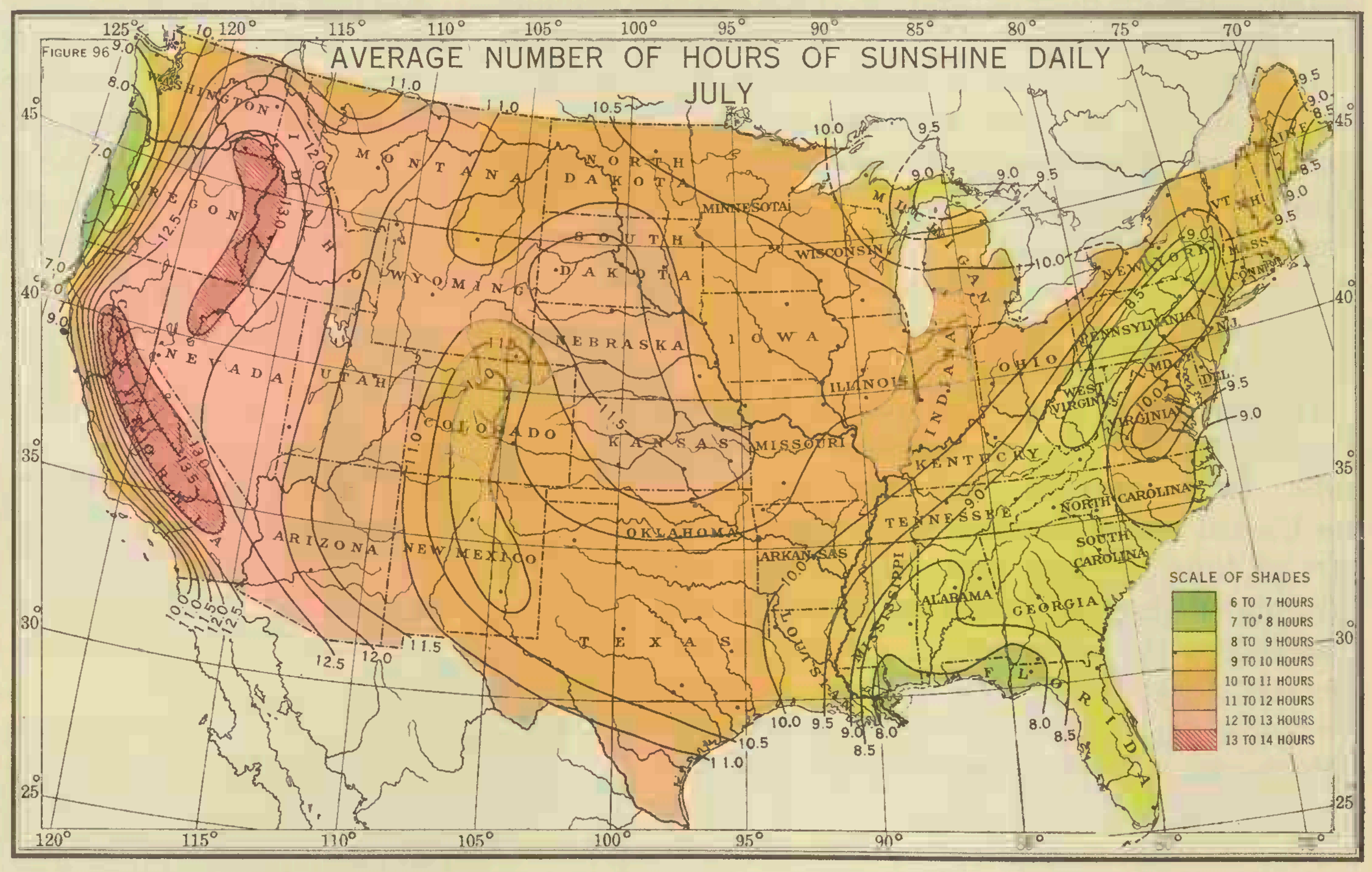


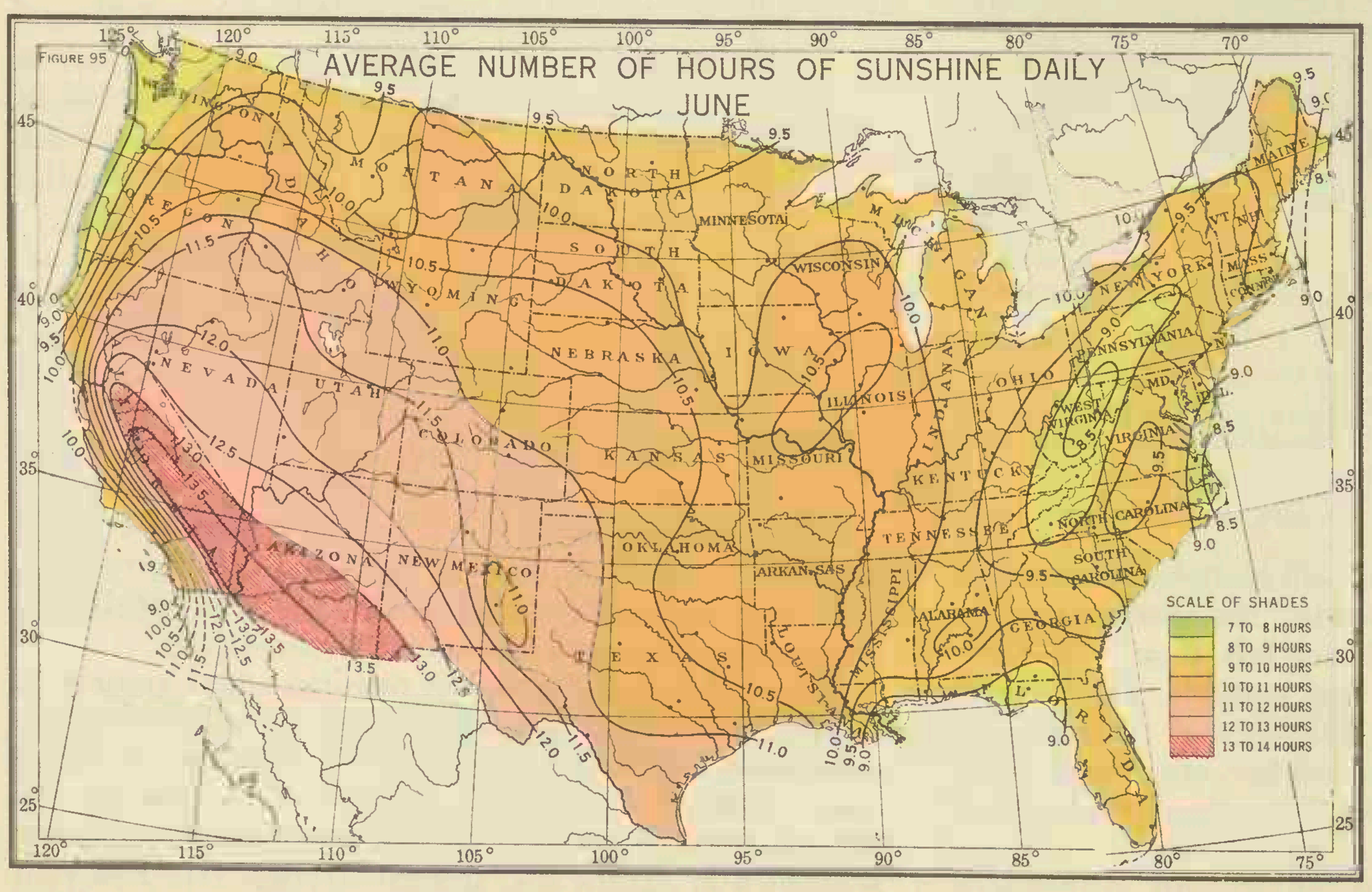


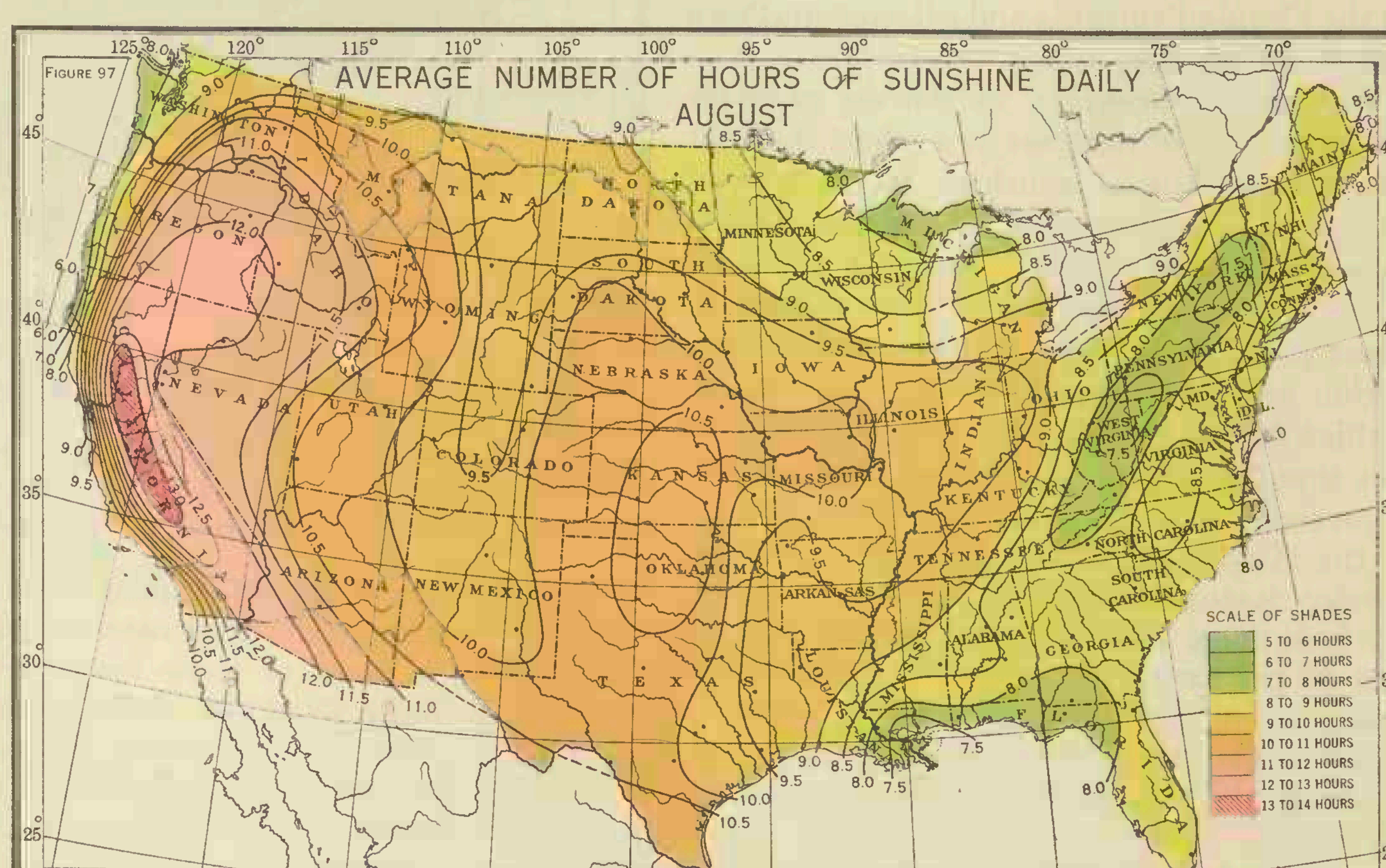


Figures 90 to 93 show for each month, from January to April, inclusive, the average daily amount of sunshine. In winter cloudy weather prevails in the Pacific Northwest and likewise in the region of the Great Lakes. Over most of the State of Washington the average amount of sunshine received in January is only about 2 hours daily and in much of the Lake region it is only slightly more, but in the far Southwest the average daily amount in this month is nearly 8 hours. With the advent of spring the amount of sunshine increases rapidly in the northern portion of the country and less rapidly in the southern. In the Pacific Northwest and in the Great Lakes region the average amount of sunshine daily in April increases to about 7 hours. In the lower Colorado River Valley the sun-shines in April, on the average, more than 12 hours daily, which is in excess of 90 per cent of the possible amount. In the central and eastern United States the amount of sunshine in April averages 6½ to 8½ hours per day, except in the northern Appalachian region, where less than 6½ hours are received

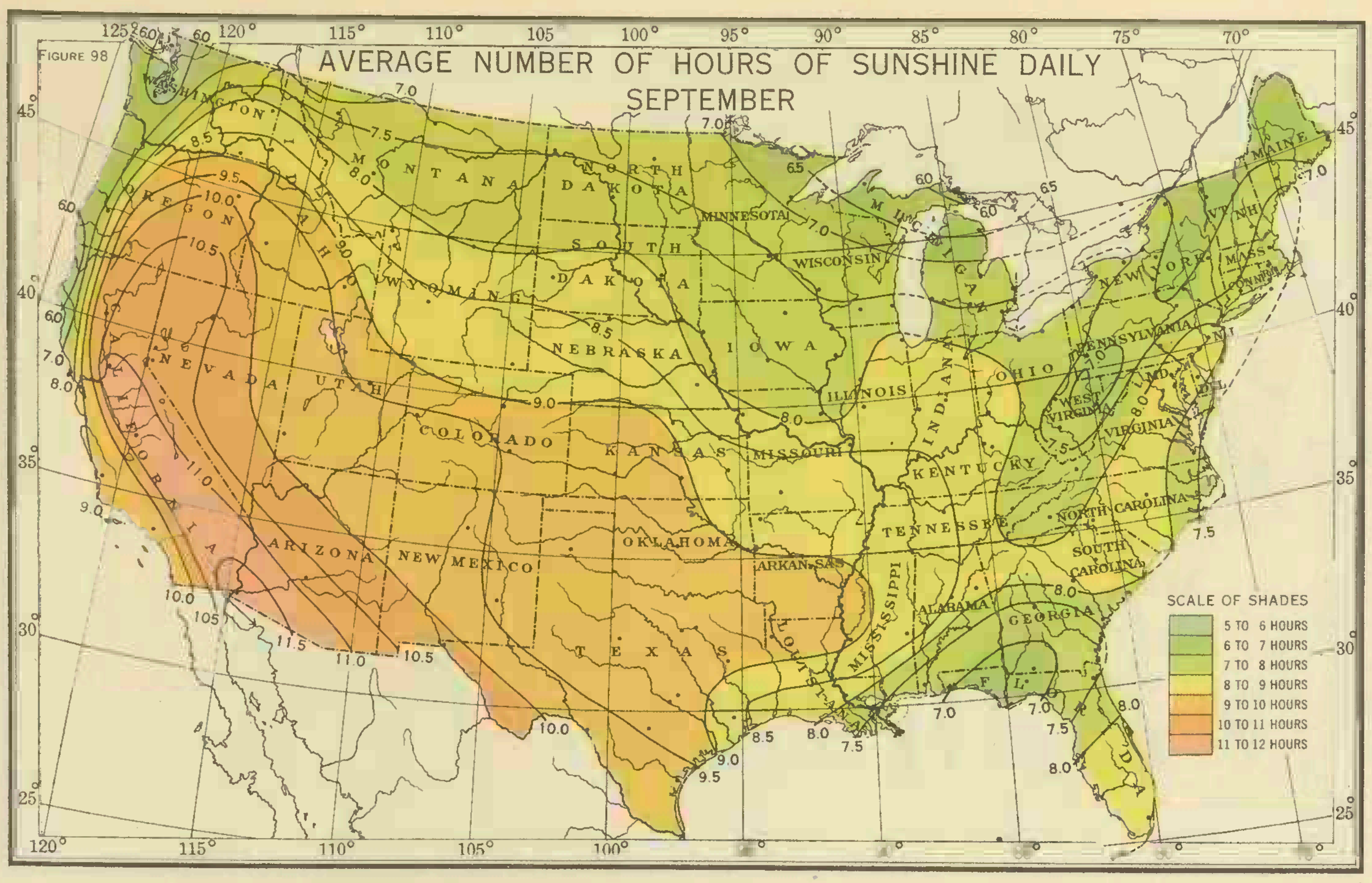


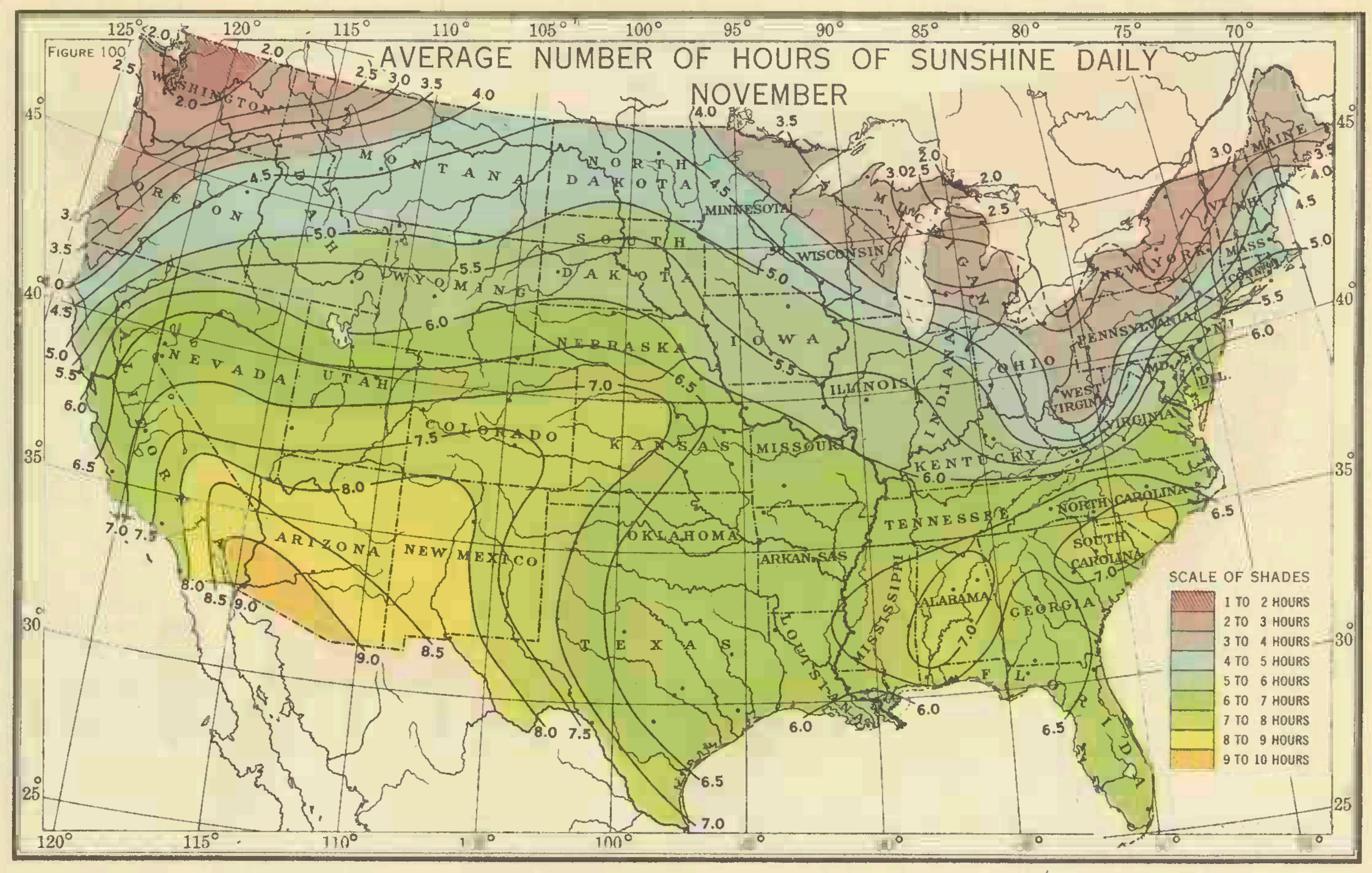


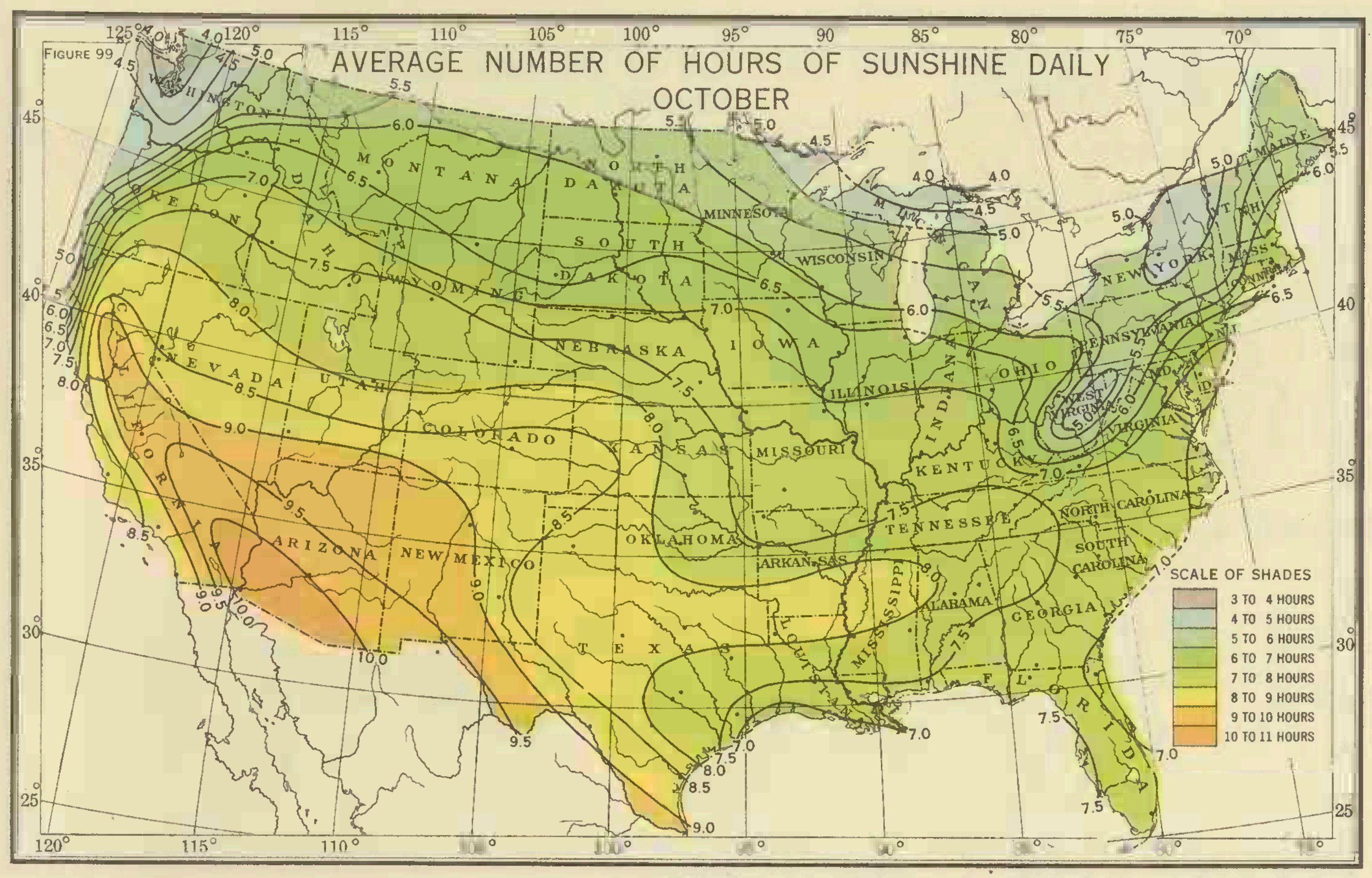


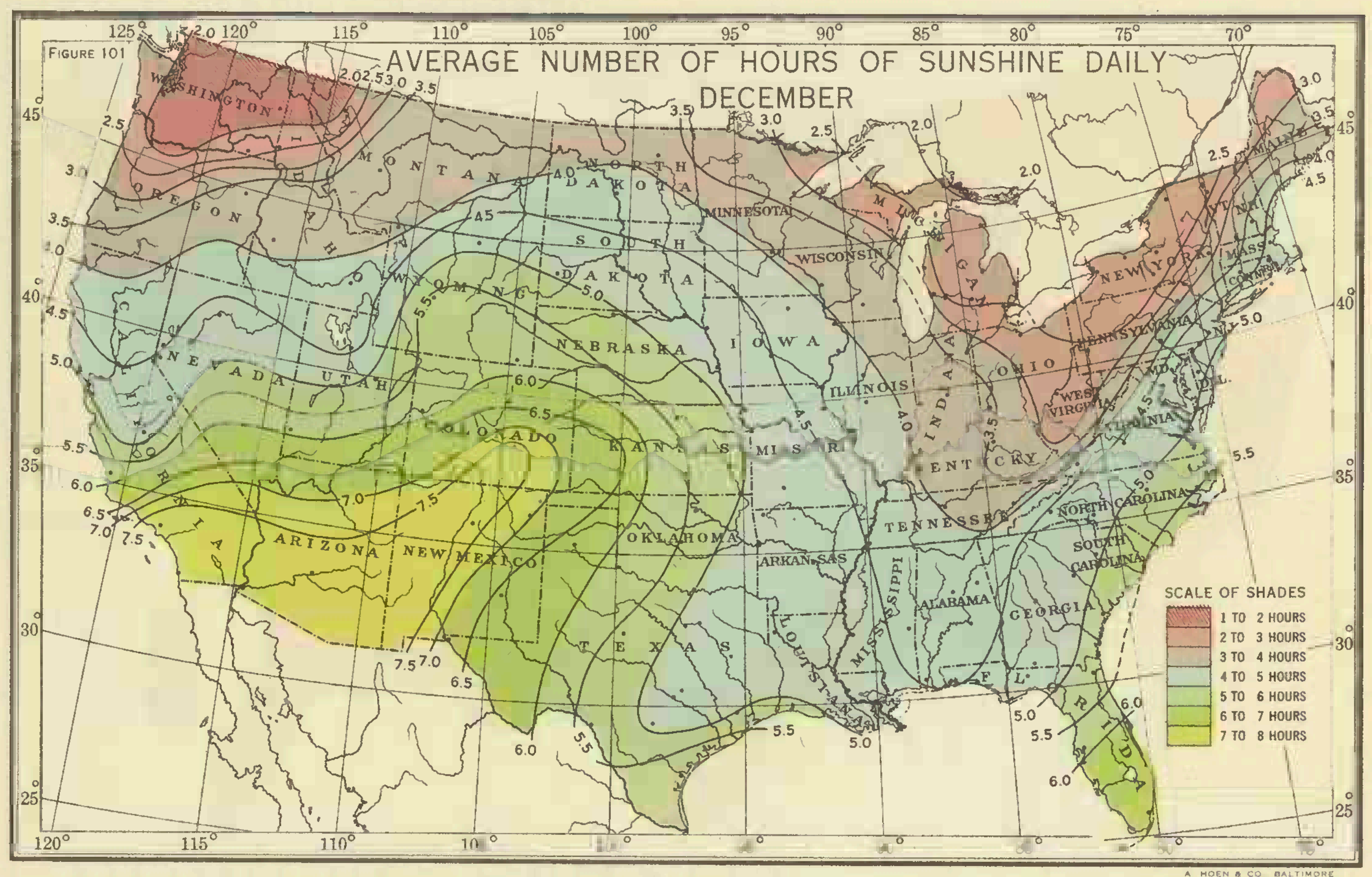


Figures 94 to 97 show for each month from May to August, inclusive, the average amount of daily sunshine. The excess of sunshine in summer over that of winter is much more pronounced in the North than in the South. East of the Rockies the geographic distribution of sunshine in summer is the reverse of winter, the Northern States receiving more than the Southern. In much of the central and northern Great Plains the average amount of sunshine in July is 40 to 50 per cent greater than along the central and east Gulf coast. The fewest hours of sunshine in the summer months are recorded along the north Pacific coast, and in the central Appalachian Mountain region, where about one-half, or slightly more, of the possible amount is received. The maximum number of hours occurs in the Great Valley of California, where there is usually almost continuous sunshine during the summer season, the average daily amount during July and August being nearly 14 hours, or about 95 per cent of the possible amount. In this region the drying of fruit in the sunshine is an important industry

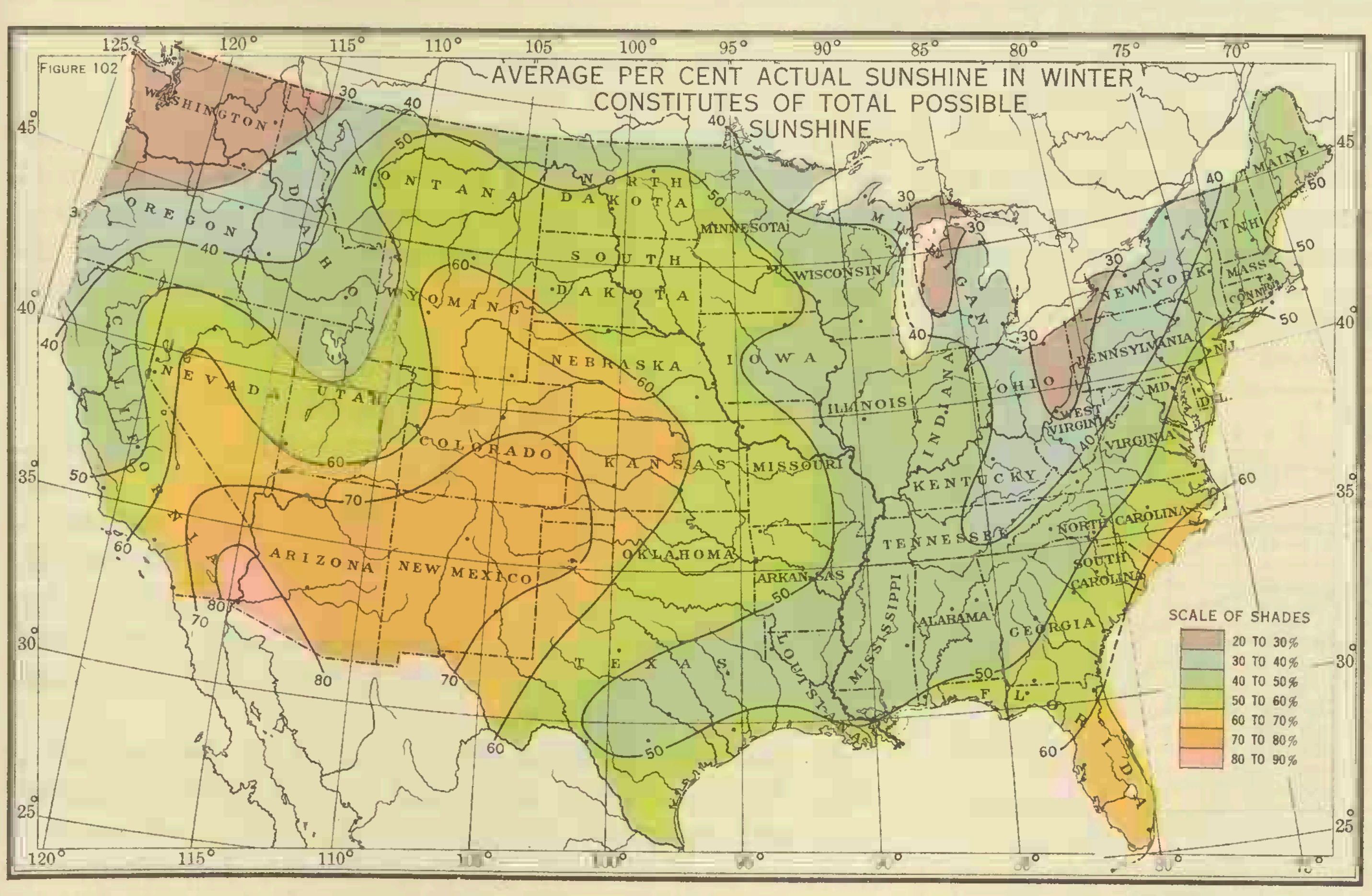


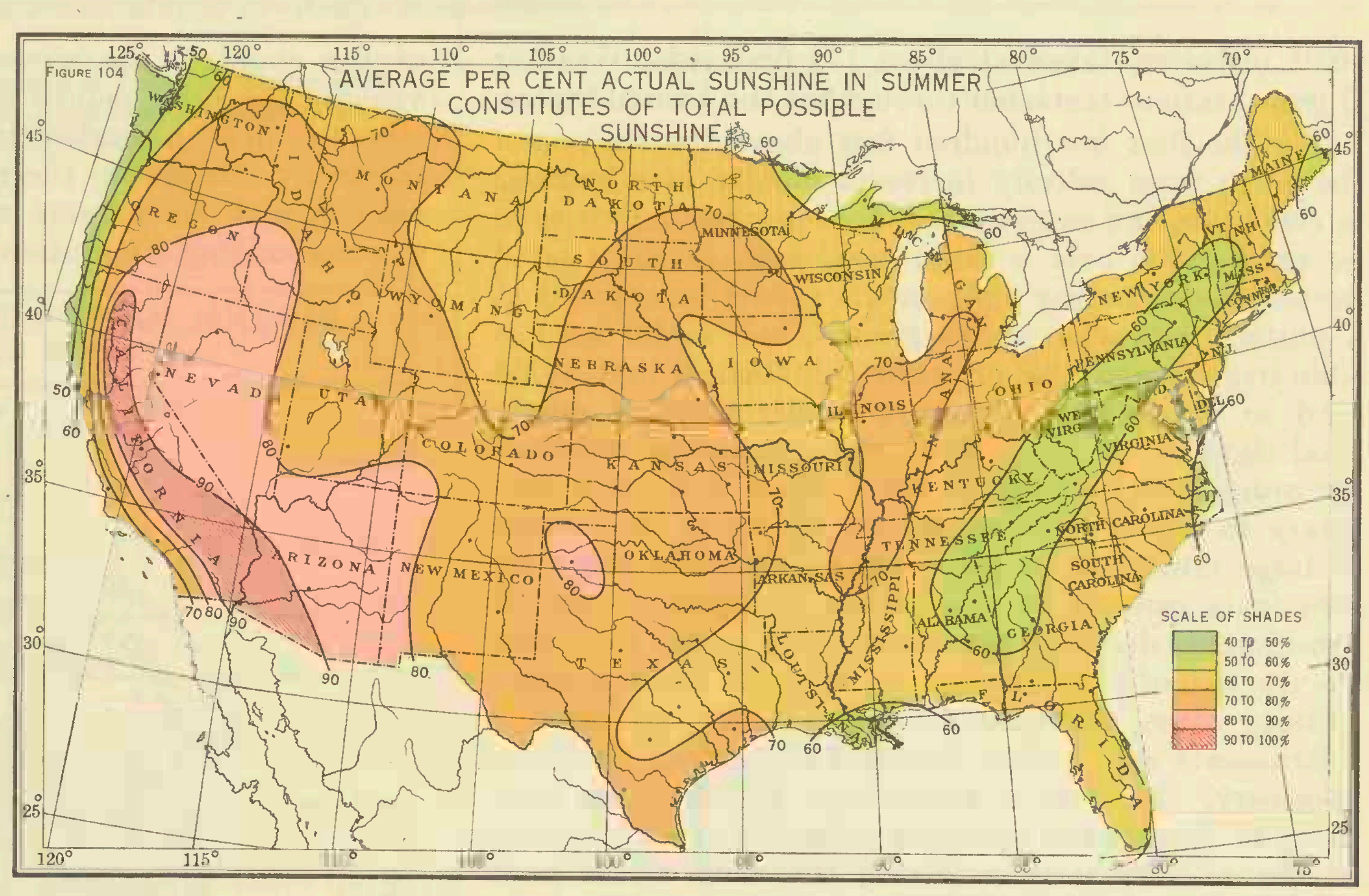


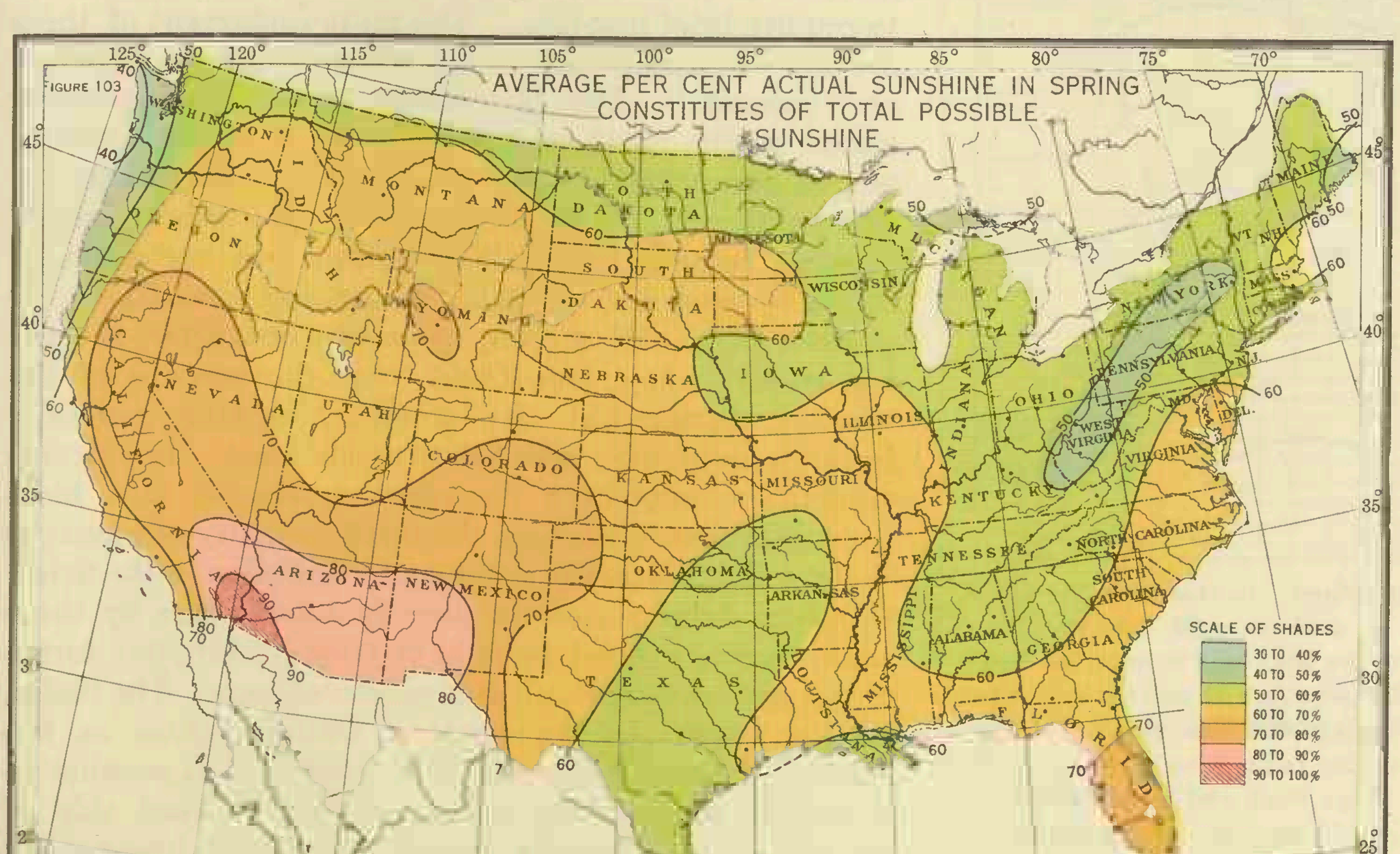


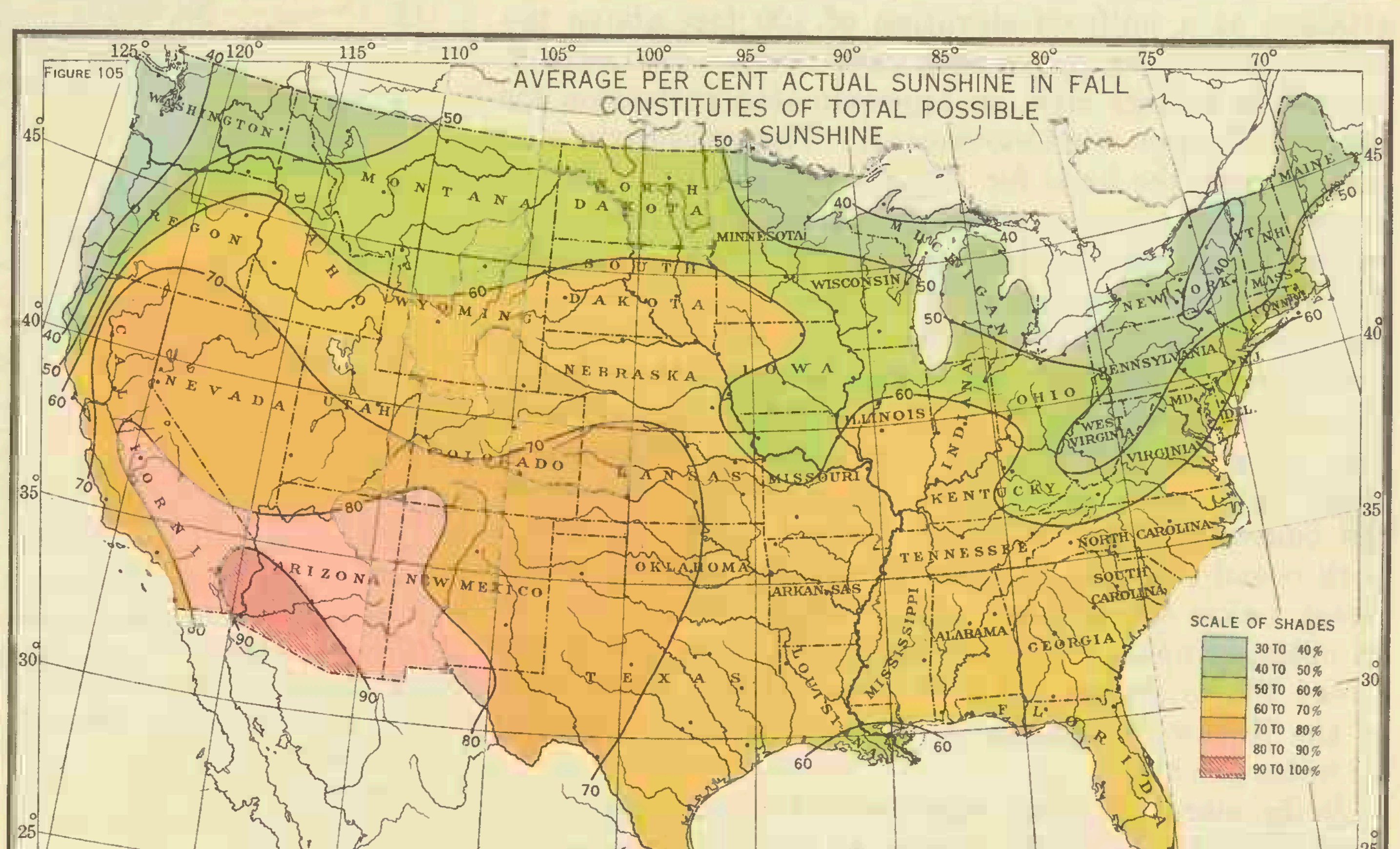


Figures 98 to 101 show for each month from September to December, inclusive, the average amount of daily sunshine. With the advance of fall there is a pronounced diminution in the amount of sunshine in all sections of the United States. This is due to the decreasing length of the days and to the increasing activity of cyclonic storms which often bring cloudy weather to large areas. During November and December cloudy weather is experienced in most of the Lake region and in the far Northwest, where at some points the average amount of sunshine received daily is less than 2 hours. The maximum amount during fall and early winter occurs in the far Southwest, where the average daily sunshine decreases from about 11 hours in September to somewhat less than 8 hours in December. The Mississippi Valley receives, in general, during September 7 to 9 hours of sunshine per day, during October from 6 to 8 hours, during November from 4 to 6.5 hours, and during December from 3 to 5.5 hours, the smaller amounts being in the Northeast and the larger amounts in the Southwest

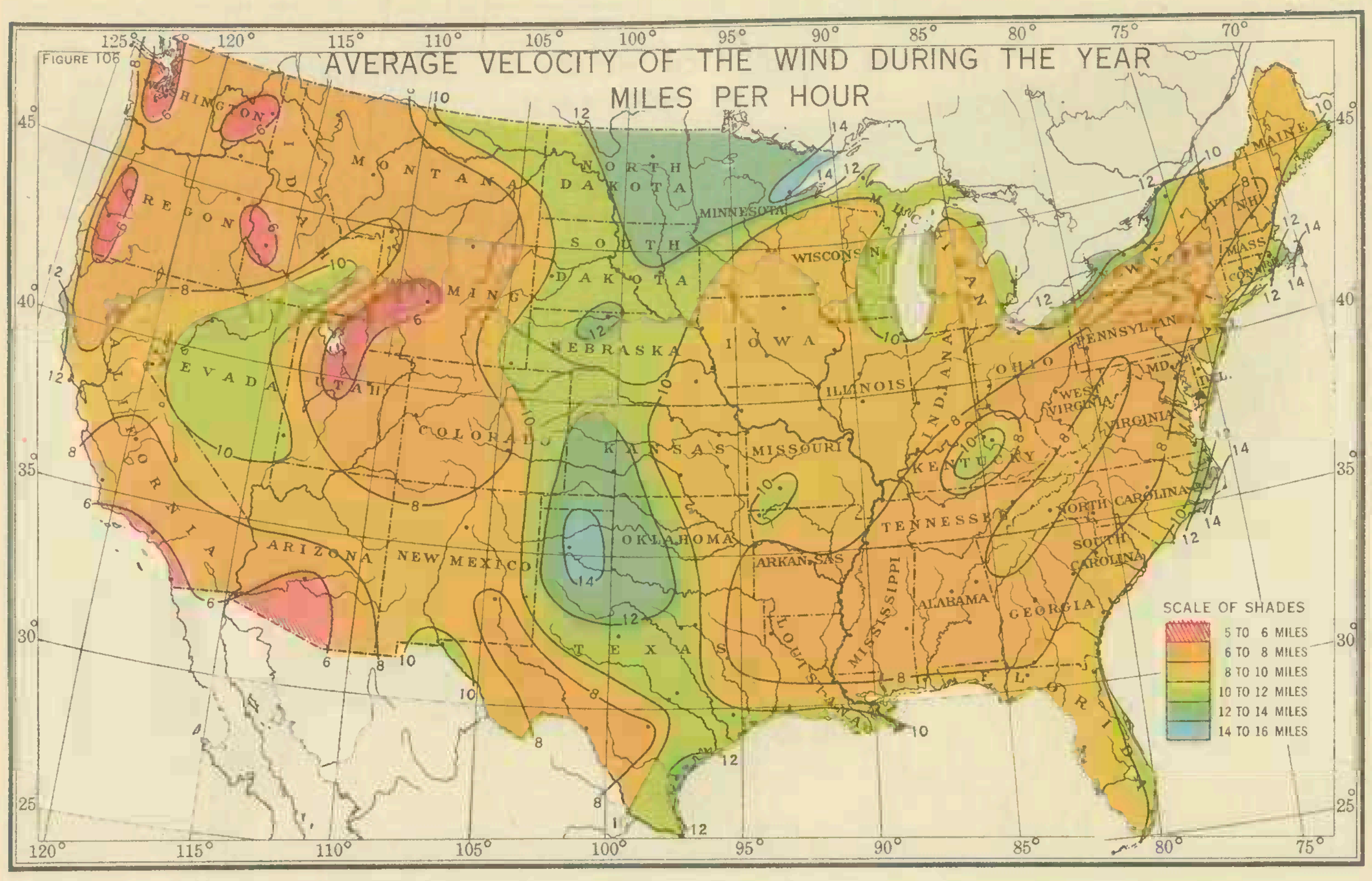


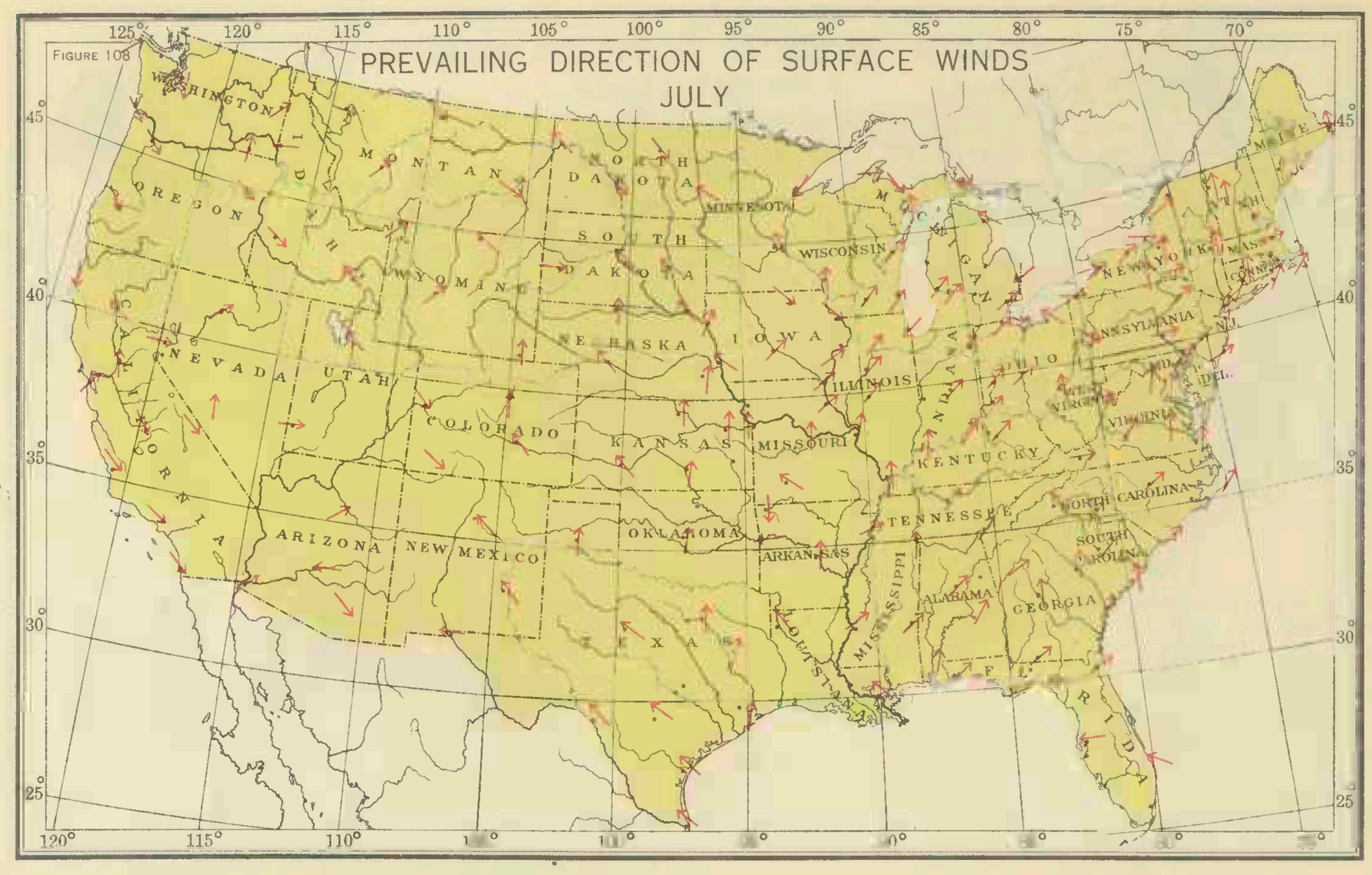


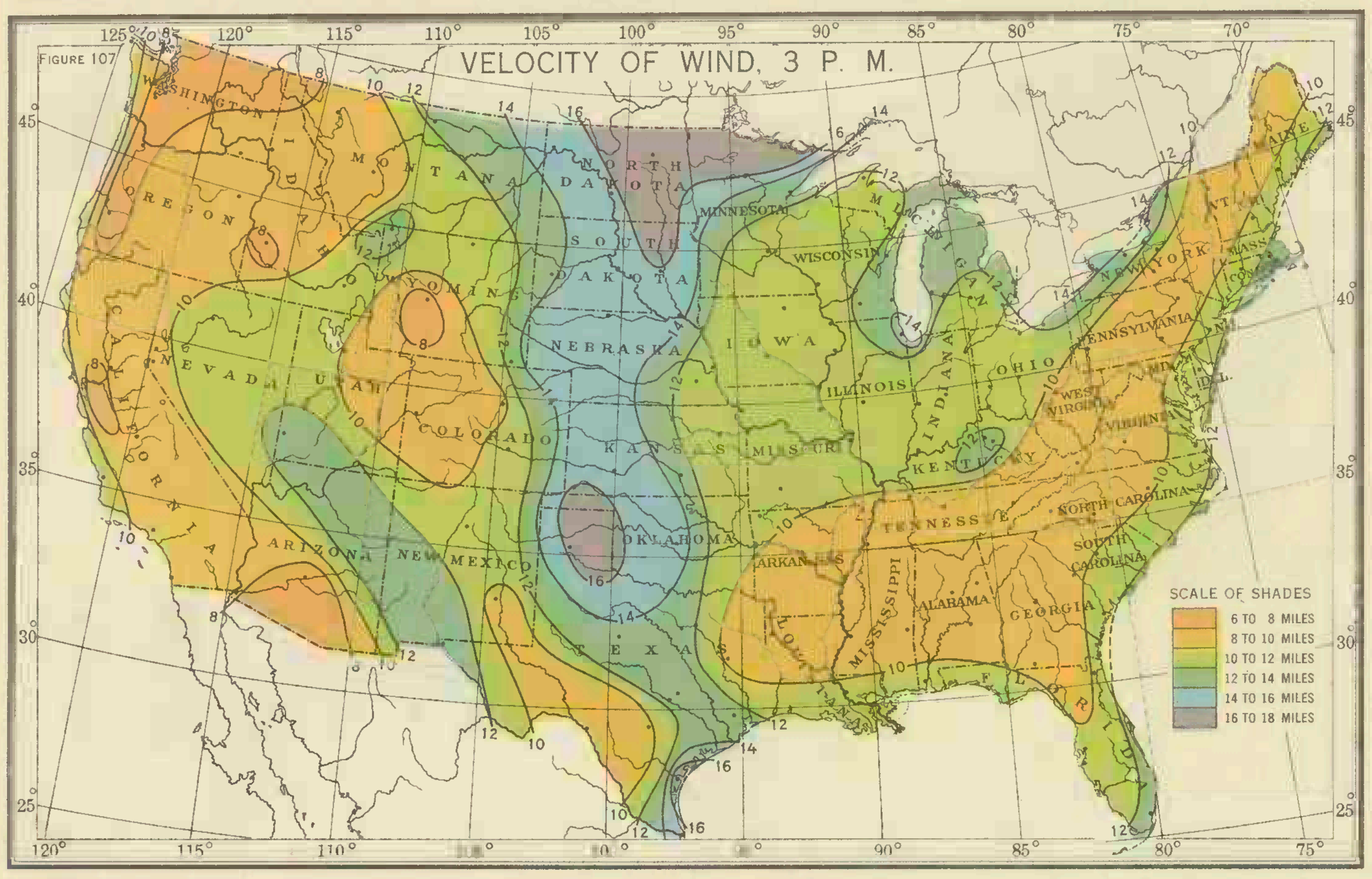




Figures 102 to 105 show for each season, winter, spring, summer, and fall, the average percentage which the sunshine actually received is of the total possible amount. These charts indicate for the different sections of the country the average proportion of the day, regardless of its length, during which the sun shines, and also show the seasonal distribution of sunshine. The minimum amount of sunshine, both actual and percentage of the possible, occurs in winter, when about half the United States, including all districts east of the Mississippi River, except the Gulf and south Atlantic coasts, receives on the average less than half the amount of sunshine that would occur with continuously clear sky. The maximum amount of sunshine, both absolute and relative, occurs in summer, when practically the entire country, except the north Pacific coast and the Appalachian Mountain region, receives more than 60 per cent of the possible amount of sunshine. In the lower Colorado River Valley and in the Great Valley of California the sun shines during the three summer months during more than 90 per cent of the hours from sunrise to sunset







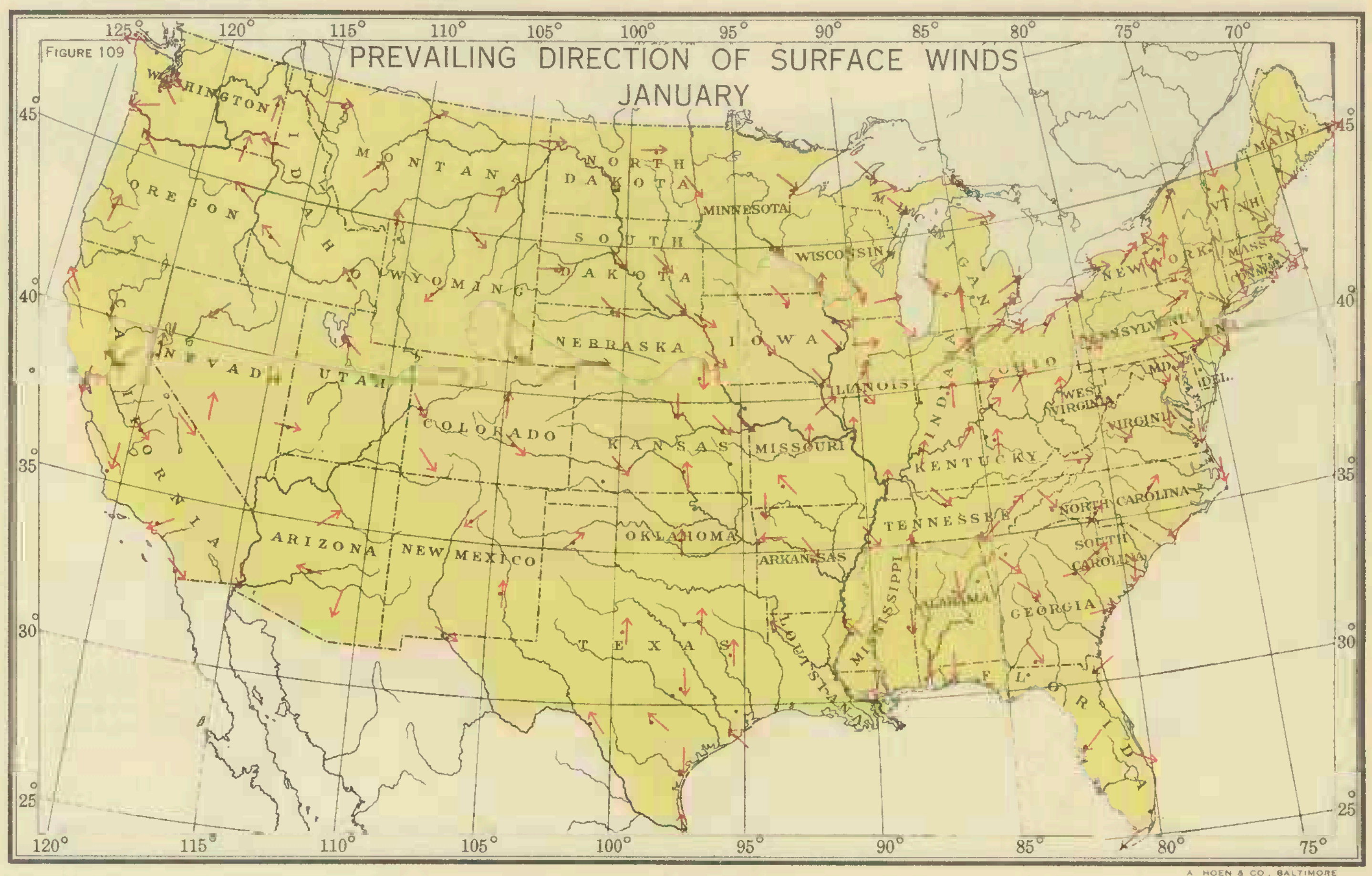


Figure 106 shows the average velocity of the wind during the year in miles per hour, estimated for a uniform elevation of 100 feet above the surface of the earth. As a rule the highest average wind velocities occur in the Great Plains region from northern Texas northward and along the coasts of large bodies of water, where the average velocity reaches 12 to 14 miles an hour. The smallest wind movement occurs, as a rule, in the protected valleys of the West and Southwest, where at some places the average annual velocity is less than 6 miles per hour

Figure 107 shows the average velocity at 3 p. m., which is usually the time of the greatest wind movement during the 24-hour period. The average velocity at this hour is from 2 to 4 miles greater than that for the entire day

Figures 108 and 109 show the prevailing direction of the wind during the months of January and July, respectively, the direction being indicated for each station by an arrow flying with the wind. In winter, winds from a westerly or northerly direction are of frequent occurrence; but in summer, especially east of the Rocky Mountains, southerly winds are, in general, of most frequent occurrence and of longest duration

1910, inclusive, taken at about 175 first-order Weather Bureau stations scattered throughout the United States.

For the first few hundred feet above the surface of the earth wind velocity increases rapidly with increase in elevation, and consequently for observed velocities to be comparable over a large area, such as the United States, the recording instruments should be exposed at a uniform elevation above ground, and as far as possible free from natural or artificial influences that would tend to vitiate the records or render them of purely local significance. Owing to the commercial demands for prompt meteorological information it is often necessary to locate Weather Bureau offices in the centers of large cities, where good exposure for the wind instruments can not be had except by placing them at considerable distances above the ground, and even then the erection of new and taller buildings in the immediate vicinity often interferes with the proper exposure of instruments and renders frequent changes in elevation necessary. In view of these facts an effort has been made to correct the recorded velocities at each station to the velocity it is estimated the wind would have attained at a unifrom elevation of 100 feet above the ground, and applying, in each case where the station is located in a large city, an approximated correction for the city effect on wind movement. These approximated values form the basis for Figures 106 and 107. In the mountainous districts of the west the data refer only to the lower valleys, where practically all the first-order Weather Bureau stations are located. No attempt has been made to show conditions at the higher elevations.

Geographic variation in wind velocity.—Over other than water surfaces the highest wind velocities, as a rule, occur in regions with large expanses of comparatively level land, such as the Great Plains, and along the coasts of large bodies of water. At points along both ocean coasts and in the immediate vicinity of the Great Lakes the average annual wind velocity is 12 to 14 miles, or more, per hour, which is also the case in the Great Plains region, whereas over other districts east of the Rocky Mountains it ranges generally from 8 to 10 miles per hour.

Daily march of wind velocity.—The daily march of wind velocity as a rule, except at high elevations, follows closely that of temperature. the minimum occurring soon after sunrise and the maximum in the afternoon, near the hour of maximum temperature. The average velocity at 3 p. m. local standard time, shown in Figure 107, is from 2 to 4 miles per hour greater than the average for the day, as shown in Figure 106. Figure 110 shows for Dodge City, Kans., representing the interior of the country, the average diurnal march of wind velocity for each month in the year. The action of the sun's heat in accelerating wind movement is clearly shown by this graph, there being a regular increase in velocity with the increase in power of the sun's rays and a corresponding diminution in the wind movement with

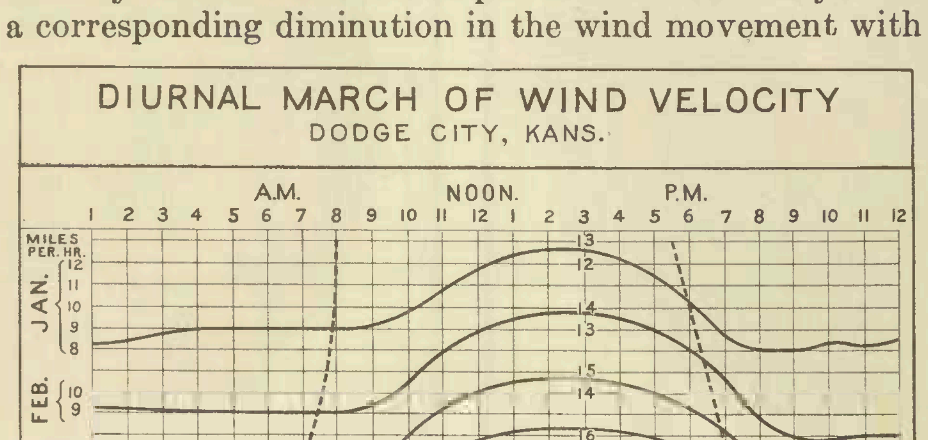


Figure 110 shows for Dodge City, Kans., representing the Great Plains region, the diurnal march of surface wind velocity. This follows closely the changes in temperature from hour to hour, the minimum velocity of the day occurring soon after sunrise and the maximum from two to six hours after noon, varying with the season. In high altitudes the daily march of wind velocity is the reverse of that at the lower levels, the midday winds on Pikes Peak and Mount Washington, for example, averaging only 75 to 85 per cent of the velocity at midnight

decreasing temperature. Near the earth's surface the average increase in wind movement during the daylight hours over that at night ranges generally from 20 to 40 per cent and is more pronounced in arid regions. The daily march of wind velocity in elevated mountain districts is the reverse of that at low altitudes.

Prevailing wind direction.—The normal direction of the surface winds in the United States in January and in July is shown in Figures 108 and 109, respectively. In winter, winds from a westerly or northerly direction are most frequent, but in summer the prevailing direction in most districts is southerly, especially from the Rocky Mountains eastward. The prevailing direction for the year as a whole is from some westerly point in most sections of the United States.

Although practically the whole of the United States lies within the region of the "westerlies," common to all middle latitudes, the weather is largely controlled by the movements of areas of low and high barometric pressure and the attendant characteristic winds peculiar to each. These cause, particularly in winter, the frequent alternation of warm, moist southerly winds, with cold, dry northerly winds, which when severe are commonly called "cold waves."

In addition to these interruptions to the prevailing wind direction there are other special winds of uncertain and irregular occurrence, but with such marked features and of such general climatic importance as to require brief mention. The most important of these are the "blizzard," the "hot winds," and the "foehn" or "chinook." The blizzard is an occasional winter visitor in the northern interior portion of the country, and in exceptional cases extends far to the southward and eastward. It is an intensely cold wind, usually blowing from a northerly direction and accompanied by snow and ice crystals, continuing sometimes for several days. Of directly opposite character are the hot winds, which sometimes visit the interior of the country during hot, dry weather, blowing generally from the southwest with considerable force. In extreme cases they have been described as similar to a blast from a furnace, absorbing the small quantity of moisture in the soil and literally drying up vegetation in the fields. Immense damage may be done in a few hours by these winds during critical periods of crop growth, but fortunately their occurrence is comparatively rare. The foehn, locally known in the western United States as the chinook, is usually a warm, dry wind, and is peculiar to mountain regions. It occurs on the leeward side of mountains and usually begins as a light breeze, but frequently increases to high velocities. The warmth and dryness of these winds rapidly melts and evaporates the snow which makes it possible for animals, exposed without shelter, to obtain food. Their influence at times extends to a considerable distance onto the plains bordering the Rocky Mountains on the east.

JOSEPH BURTON KINCER.

ISSUED JULY 15, 1918

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

ATLAS
OF
AMERICAN AGRICULTURE

PREPARED UNDER THE SUPERVISION OF O. E. BAKER, AGRICULTURIST
OFFICE OF FARM MANAGEMENT, W. J. SPILLMAN, CHIEF

CLIMATE

CONTRIBUTION FROM THE U. S. WEATHER BUREAU, CHARLES F. MARVIN, CHIEF

FROST AND THE GROWING SEASON

BY

WILLIAM GARDNER REED
ASSISTANT IN AGRICULTURAL GEOGRAPHY, OFFICE OF FARM MANAGEMENT

PREPARED UNDER THE JOINT DIRECTION OF P. C. DAY, CLIMATOLOGIST
U. S. WEATHER BUREAU, AND O. E. BAKER, AGRICULTURIST
OFFICE OF FARM MANAGEMENT

WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

SELECTED REFERENCES ON FROST

NOTE: References marked with asterisks (*) contain discussions of methods of frost protection.

Ballantyne, A. B.: Blooming periods and yields of fruit in relation to minimum temperatures. Utah Agr. Exp. Sta. Bul. 128, p.245–261, 10 figs. Logan, 1913.

Batchelor, L. D., & West, F. L.: Variation in minimum temperatures due to the topography of a mountain valley in its relation to fruit growing. Utah Agr. Exp. Sta. Bul. 141, 27 p.,20 figs. Logan, 1915.

Chandler, W. H.: The killing of plant tissues by low temperature. Missouri Agr. Exp. Sta. Research Bul. 8, p.143–309, 3 pls., chart. Columbia, 1913.

Cox, Henry J., & others: Frost warnings. *In* U. S. Weather Bur., Weather forecasting in the United States, p.177–215, figs. 97–124. Washington, 1916.

Day, P. C.: Frost data of the United States. U. S. Weather Bur., Bul. V, 5 p., 5 maps. Washington, 1911. *This bulletin is superseded by the section on* FROST AND THE GROWING SEASON *in this* ATLAS.

Fassig, Oliver L.: The period of safe plant growth in Maryland and Delaware. U. S. Weather Bur., Mo. Weather Rev., vol. 42, p.152–158, table, 10 figs. (incl. maps). Washington, 1914.

***Frost.** By various authors *in* The encyclopedia of practical horticulture, Granville Lowther, editor, vol. 2, p.1006–1029, incl. maps, ills. North Yakima, 1914.

Garriott, Edward B.: Cold waves and frosts in the United States. U. S. Weather Bur., Bul. P, 22 p., 328 charts. Washington, 1906.

***Garriott, E[dward] B.**: Notes on frost. U. S. Dept. Agr., Farmers' Bul. 104, 35 p., 4 figs. Revised by Alexander G. McAdie, August, 1911. Washington, 1911.

Henry, Alfred J.: [Mountain and valley temperatures] *6 papers under various titles.* U. S. Weather Bur., Bul. Mt. Weather Observ., vol. 3, p.201–225, incl. tables, 5 figs. (1910); vol. 4, p.103–114, incl. tables, 1 fig. (1911); vol. 4, p.305–306, incl. table (1912); vol. 4, p.310–341, incl. tables, 10 figs. (1912); vol. 5, p.1–18, incl tables, 5 figs. (1912); vol. 6, p.35–37, incl. tables (1913). Washington, 1910–1914.

***McAdie, Alexander [G.]**: Temperature inversions in relation to frost. Annals, Harvard College Observ., vol. 73, p.168–177, 4 pls. Cambridge, 1915.

***McAdie, Alexander [G.]**: The theory and practise of frost fighting. Scientific Mo., vol. 1, p.292–301, 6 figs. New York, 1915.

***Reed, William Gardner**: Frost in the United States. *In* Second Pan American Scientific Cong., Proc., vol. 2, incl. tables, 13 figs. *In press.* Washington, 1917.

Reed, William Gardner: The probable growing season. U. S. Weather Bur., Mo. Weather Rev., vol. 44, p.509–512, 4 figs. Washington, 1916.

Reed, William Gardner, & Tolley, Howard R.: Weather as a business risk in farming. Geog. Rev., vol. 2, p.48–53, incl. tables, 4 figs. New York, 1916. *Abstract in* U. S. Weather Bur., Mo. Weather Rev., vol. 44, p.354–355. Washington, 1916.

Smith, J. Warren: Predicting minimum temperatures for frost protection. Ohio Naturalist, vol. 15, p.405–408, 1 fig. Columbus, 1915.

Spillman, W. J., & others: The average interval curve and its application to meteorological phenomena. U. S. Weather Bur., Mo. Weather Rev., vol. 44, p.197–200, incl. tables, 2 figs. Washington, 1916.

***U. S. Weather Bureau** (Humphreys, W. J., & others): Papers on frost and frost protection in the United States. *Reprinted from* the Mo. Weather Rev., vol. 42, p.562–592, incl. tables, maps, diagr., photos. Washington, 1915.

***Wilson, Wilford M.**: Frosts in New York. New York Cornell Agr. Exp. Sta., Bul. 316, p.505–544, figs. 135–151. Ithaca, 1912.

BIBLIOGRAPHY OF FROST AND FROST PROTECTION.

Buynitzky, Eleanor: A selection of books and papers . . . on [frost] . . . forecasting. *In* U. S. Weather Bur., Weather forecasting in the United States, p.357–358. Washington, 1916.

Reed, William Gardner, & Feldkamp, Cora L.: A selected [annotated] bibliography of frost in the United States. U. S. Weather Bur., Mo. Weather Rev., vol. 43, p.512–517. Washington, 1915.

U. S. Department of Agriculture: Experiment Station Record, Washington, monthly. (Current.)

U. S. Weather Bureau: Bibliography in Monthly Weather Review. Washington. (Current.)

SOURCES OF FROST DATA.

U. S. Weather Bureau: Summaries of climatological data of the United States by sections (tables). Various dates. *Each section is revised and reprinted when the previous edition is exhausted.* Summaries for the whole United States were collected as U. S. Weather Bureau Bul. W. Washington, 1912.

U. S. Weather Bureau: Climatological data for the United States by sections (tables), 13 numbers a year (12 monthly and No. 13, annual summary) since 1914. "Printed at the several Section Centers, assembled and bound at the Washington Office for service use and exchange." (Current.)

U. S. Weather Bureau: Monthly Weather Review, Washington. Monthly. (Current.)

U. S. Weather Bureau: National Weather and Crop Bulletin, Washington, weekly during the crop-growing season (April–September), monthly during the remainder of the year. (Current.)

INSTRUCTIONS FOR REPORTING FROST.

U. S. Weather Bureau: Instructions for cooperative observers. Circulars B and C, Instrument Division, ed. 5. Washington, 1915.

FROST AND THE GROWING SEASON

Definition of Frost.—The occurrence of the last frost in spring and the first in fall are especially noted by the observers of the Weather Bureau. Three distinctive frost types, based on degrees of severity, are recognized, namely, "light," "heavy," and "killing." A frost that has no destructive effect, although tender plants and vines in exposed places may be injured, is recorded as "light." The designation "heavy frost" is descriptive of a condition that in itself is more severe than a light frost—that is, the deposit of frost is heavier and the temperature falls to a lower point, although the staple products of a locality are not seriously injured. The term "killing frost" is used to define a frost, or temperature condition, of sufficient severity to be generally destructive to the staple products of the locality. The distinction between the terms "heavy frost" and "killing frost" is one that has reference more to the effect of the frost than to the amount of deposit. Two frosts may appear equally severe so far as the deposit is concerned, yet little damage may be done by one, while the other may be generally destructive to vegetation. In such cases the former is recorded "heavy frost" and the latter "killing frost."

A low temperature condition of sufficient severity to be destructive to vegetation may, in fact often does, occur without an actual deposit of frost, because of cloudiness, or other cause. Such an occurrence is considered equivalent to a "killing frost" because the effect on vegetation is much the same as that occasioned by an actual deposit of frost sufficient to cause destructive effects. It occasionally happens in spring that vegetation has not advanced sufficiently to be injured by frost at the time of its last occurrence, and in the fall the staple crops may have matured before the occurrence of the first killing frost, making it difficult to determine by direct observation the proper killing-frost dates. In such cases the last date in spring on which a temperature of 32° F. was recorded, or the first similar condition in fall, is regarded as the date of the last or the first killing frost. Frosts less severe than killing are in most cases of minor significance to agriculture, although the difference between killing frost and those less severe is often a matter of opinion of individual observers. Records of the occurrence of frosts have been kept since the establishment of the Weather Bureau in 1871 and by many people interested in agriculture or climatology for varying periods. The longest available records are those for Peoria, Ill. (see fig. 88.) and St. Augustine, Fla., each of which began in 1856.

The Occurrence of Killing Frost.—Frosts are of agricultural significance only when they occur at the time of year that vegetation is active. During the winter months they are of little significance to agriculture except in limited areas in the South and Southwest; during the summer, except in some of the more elevated areas, they do not occur. Dangerous frosts in the spring are those which occur after growth has begun. Frost occurs spasmodically and large areas are subject to visitation on the same date. A period then frequently follows without frost over the whole area. Later frost may occur covering another large area generally not coextensive with the first.

Characteristic types of frost weather are shown by the three series of weather maps, figures 93 to 102 The six maps on the upper part of the page show the advance of low temperature conditions over the Gulf States and Florida for two severe frosts, one an early spring frost and the other a late fall frost. The four maps of the western part of the country show weather conditions accompanying a severe frost in southern California. These maps, selected from a large number on file at the Weather Bureau, have been introduced to show conditions favorable to the occurrence of frost. Frost conditions are complicated and the ability to recognize weather types indicating frost can be acquired only after considerable experience and a wide acquaintance with differing conditions shown by the weather maps. It is, however, often possible to foretell the occurrence of frost locally from the weather of the afternoon preceding, and many farmers are able to make successful local forecasts for frosts from casual observations of weather conditions during the day.

The thermograms (fig. 89) show the march of temperature at two stations in the Middle West at which killing frost in fall was reported on the morning of October 27, 1914. The rapid rise of temperature in the morning after a night with frost is characteristic, but the details of temperature changes during frosts are far from uniform.

Conditions Favoring Killing Frost.—The occurrence of killing frost depends upon a number of conditions, among which latitude and altitude are of primary importance; the period during which frosts occur is longer in the North and in the more elevated parts of the country, but the relations between altitude and the occurrence of frost are complex. Differences in elevation in the same region are often more important than altitude above sea level. Even in the case of comparatively small differences of elevation the distribution of frost and its relative severity often present complications owing to the tendency of the coldest air to collect in the lowest parts of the region. In more or less inclosed valleys, the hillsides, possibly even the hilltops in some cases, are less subject to frosts than the valley bottoms. The problem, however, is one of great complexity, and thermal surveys of particular regions are necessary before detailed statements as to occurrence, distribution, and severity of frosts can be made with any degree of certainty.

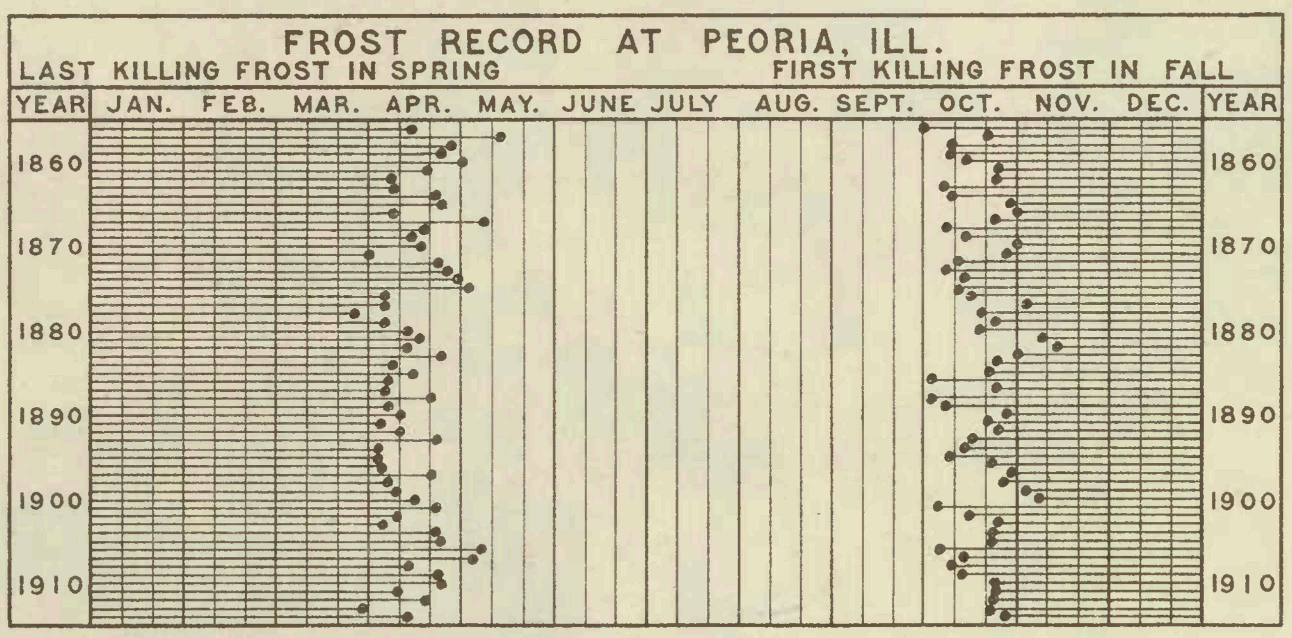


Figure 88 The dots represent the dates of occurrence of last and first killing frost in each year; the blank portion of the diagram is the time free from killing frost.

Frost Records.—Because the period available for plant growth is largely confined to the time between the last killing frost in spring and the first in fall, the dates of these frosts and the periods between them are the most significant statements of frost occurrence which can be recorded. These dates in any locality are subject to wide variations from year to year; figure 1 shows them for Peoria, Ill., for each year of the record. The shaded area shows the time of year when killing frosts occur and the unshaded area the time free from killing frosts; agriculturally these may be regarded, respectively, as the time not suitable for plant growth and the time available for the growth of crops.

Frost records are available from about 4,000 regular and cooperative stations of the Weather Bureau. Of these records about 600 cover the full period of 20 years (1895–1914), adopted for most of the climatic material in this Atlas. About 1,800 cover more than 10 but less than 20 years; the other 1,600 are for shorter periods, but none less than 5 years. The records were all made under the direction of the Climatological Service of the Weather Bureau and have been carefully verified by officials of the bureau familiar with the districts and the locations of the stations. The data represent as nearly as possible the exact occurrence of the frost dates in the years of record.

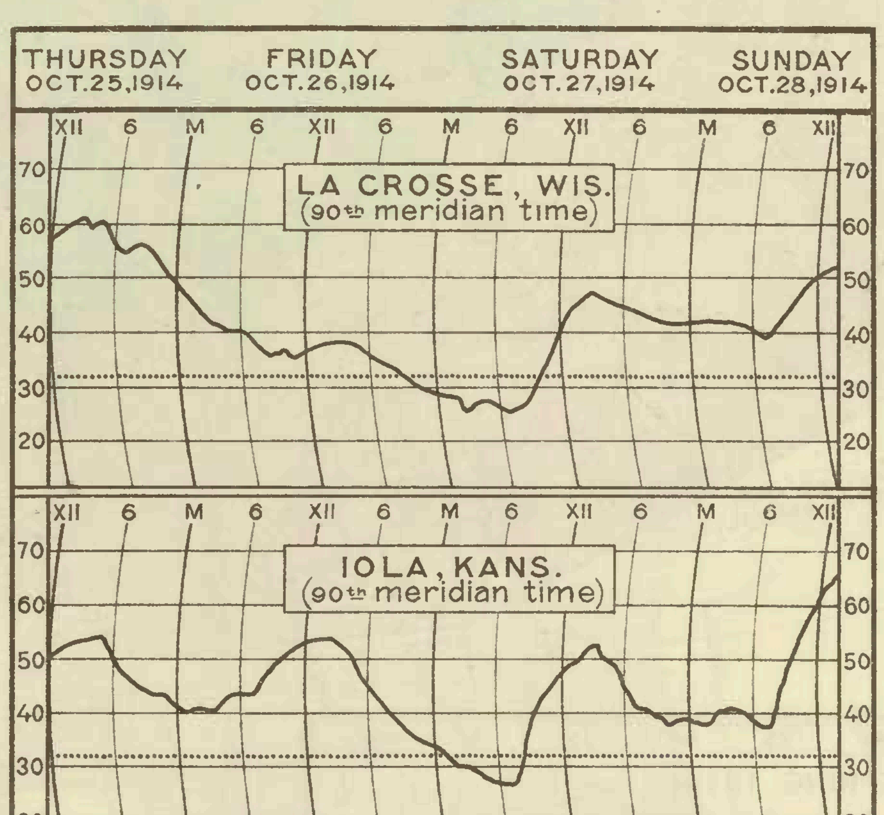


Figure 89. March of temperature at the time of killing frost at representative stations in the Middle West. Killing frost occurred on the morning of October 27.

Dispersion of Frost Dates.—The most noteworthy fact regarding these critical frost dates is their extreme irregularity. This may be seen by examining the Peoria record fig 88 and the records for other stations (see figs. 92, 104, 106, 109, 111 and 113 These diagrams show for selected stations the actual occurrence of frost in all the years of the record for each station, 59 years in the case of Peoria. The stations were selected from those having the longest records to illustrate different dispersions. The dates of these critical frosts are of agricultural significance in that they show in each year the time between which no injurious frosts occurred. As different crops require periods of varying length to reach maturity, a knowledge of the length of the season without killing frost is of importance in the selection of regions suitable for particular crops. Figure 88 shows by the blank space in the middle the length of the frostless period for each year at Peoria. Figures 105, 108 and 110 give similar information for other stations. In these diagrams the length of the line shows the period without killing frost for each year.

The irregularities are so great that some method of summarizing critical frost dates and the lengths of the periods without killing frost must be adopted when any considerable number of records are under consideration. In the case of a single station the complete record showing the dates in each year furnishes detailed information. The record at Peoria (fig. 88) shows that in the 59 years no killing frost in spring occurred after May 11 and none in fall before October 1, giving a period of 143 days during which no frost occurred in the entire 59 years. In very many years the period is longer, however, and many days available for plant growth will generally not be used if these dates are taken as the extreme limits of the growing season. The question the farmer must decide is the degree of risk he is able to incur in order to make use of this longer period. The risk involved in planting at different dates must be determined by means of the mathematical summaries which can be made on the basis of the detailed information contained in the record.

Average Dates.—The simplest of all summaries is the arithmetical average. In the case of frost the average date of last killing frost in spring is the time when the chance of killing frost falls to one in two; that is, in about half the years it will occur on or after the average date and in other years it will be earlier. For records covering less than 20 years the average is the only type of summary which can be obtained with usable accuracy. The double-page maps of average dates of last killing frost in spring and of first killing frost in fall show for the 20-year period 1895–1914 the summarized frost conditions of the United States. It should be noted, however, that on the average dates the chance of killing frost is large, crops growing on these dates being subject to frost damage one year in two on the average.

Last Killing Frost in Spring.—The average dates of last killing frost in spring are shown by figure 90 East of the Rocky Mountains lines have been drawn for the 1st, 11th, and 21st day of each month from March 1 to June 1, and from the Rocky Mountains westward for the 1st of each month only. Over the eastern section the lines trend east and west in general, although they bend more or less northerly in the proximity of bodies of water and large river valleys, while the bend is southerly in the vicinity of highlands. In the East latitude is the more general control of frost occurrence, while in the West altitude, modified by oceanic influence along the Pacific coast, is the more influential factor. This makes mapping of the western third of the United States on a small scale exceedingly difficult, and this difficulty is increased by the fact that habitations (the only places where continuous records can readily be obtained) are as a rule restricted to the lower slopes where frost conditions are less severe than in the mountains. The result is that only very general conditions can be shown for this western portion of the country, as each station presents problems peculiar to itself, and in any given area of small extent the occurrence of frost may vary considerably from that shown by the map. The complications introduced by the high mountains and deep valleys and the exceedingly irregular character of the surface have made it impossible to draw lines at intervals of less than one month.

The earliest date line shown is that of March 1. This line skirts the coast of South Carolina and of Georgia, crosses northern Florida, and extends westward through the Gulf States. Southwestern Arizona, the greater part of the Colorado Desert, the coast of southern California, and other favored regions in the West also have their last killing frost in spring before March 1. In these regions frost conditions are irregular, but killing frost occurs every year except at places having exceptionally favored locations. A line has been drawn marking off that portion of the country in which killing frost is liable to occur annually. North of this line it may be expected every year, although there is an occasional winter without it. The area south of this line, in which frost does not occur annually, includes the

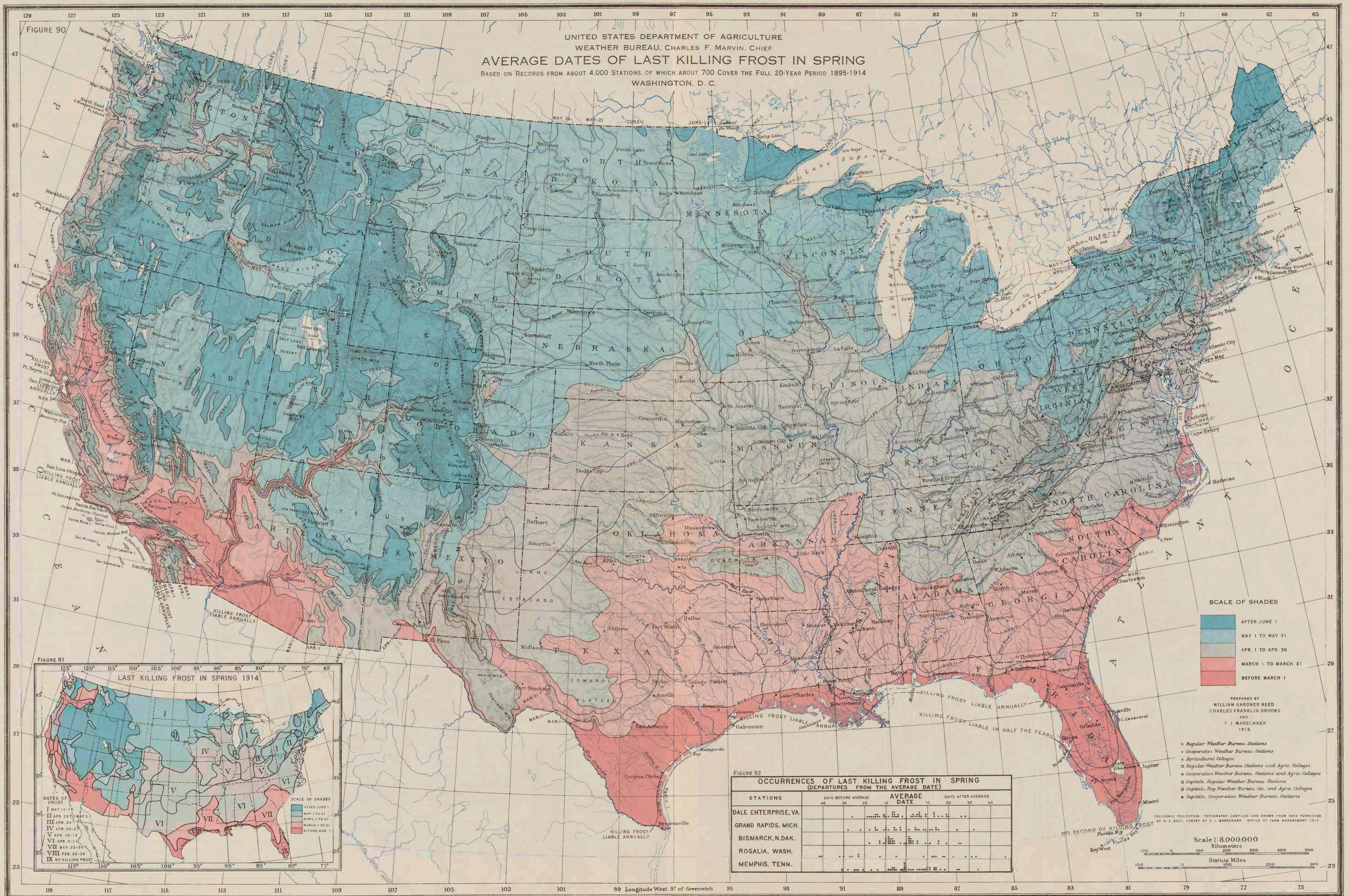
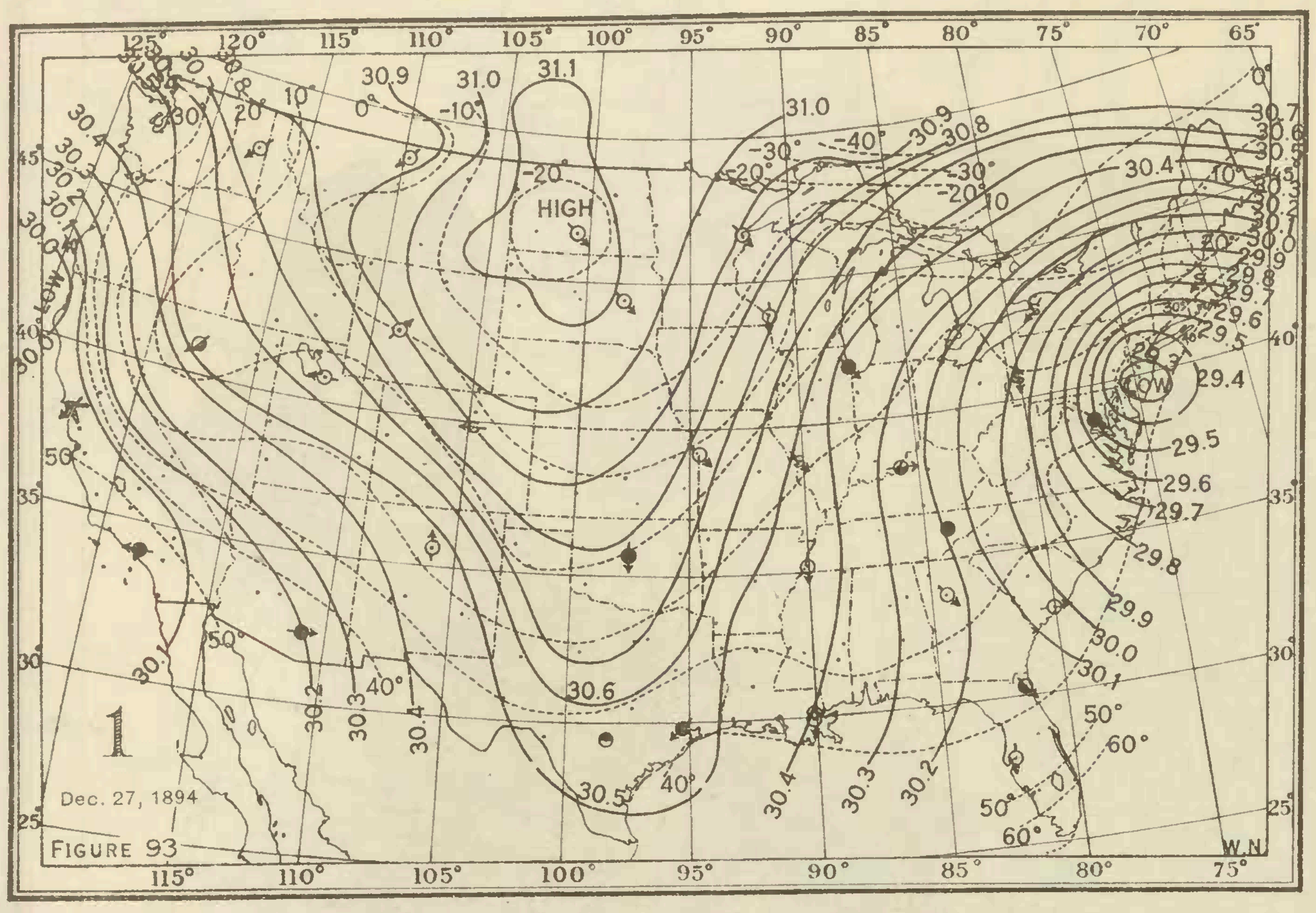
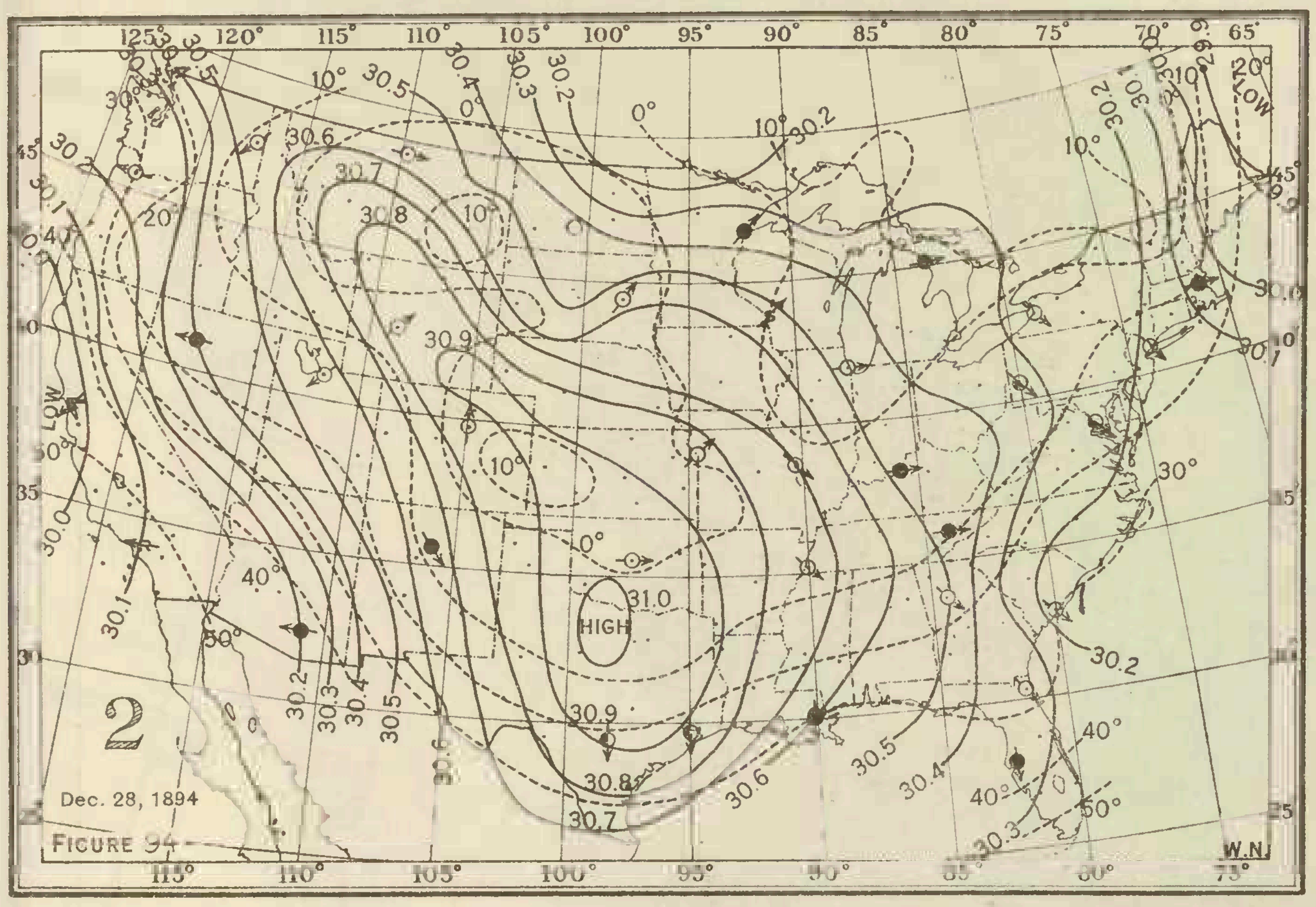


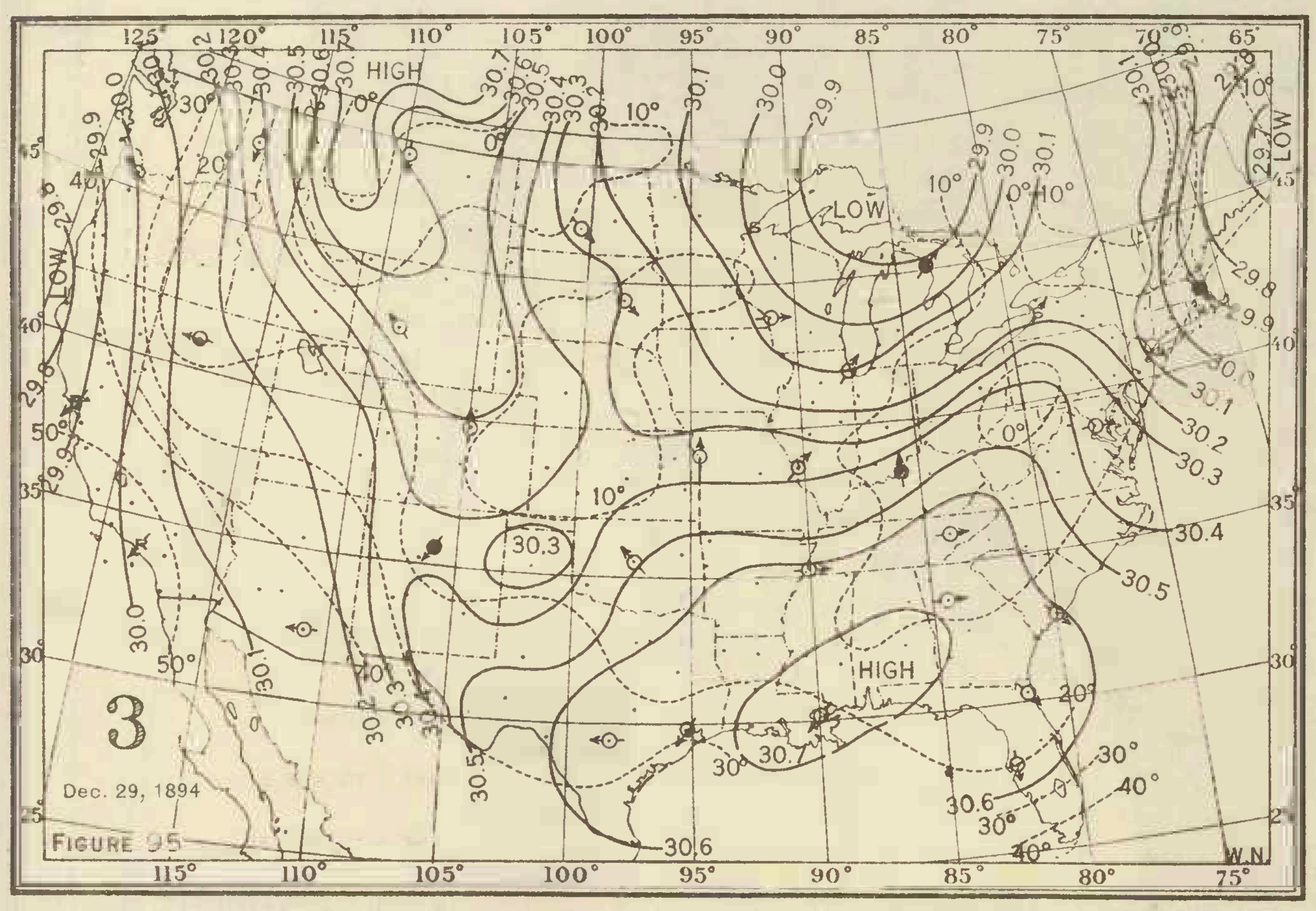
Figure 90 shows the average of the dates on which the last killing frost in spring has occurred. In the East and Middle West the lines are drawn for the 1st, 11th, and 21st of each month; from the Rocky Mountains westward for the 1st of each month only. The only Weather Bureau station in the United States where killing frost does not occur is Key West, Fla. Except for the peninsula of Florida, the coast of the Gulf of Mexico, and favored localities in Arizona and California frost occurs every winter. These localities in California are situated mostly in the foothills and along the coast of southern California and in the San Francisco Bay region. The earliest date for which it is possible to draw a line showing the average time of last killing frost in the spring is March 1, while the latest date is June 1. Occurrences of the last killing frost before March 1 and after June 1 are too irregular to permit the drawing of average date lines. Along the northern margin of the cotton belt the last killing frost in spring occurs usually about April 11, along the northern margin of the corn belt about May 11, and in northern Maine, in the Green Mountains of Vermont, in the Adirondacks, in the Iron Ranges of upper Michigan, and in northeastern Minnesota about June 1. At the higher elevations in the West there are large areas utilized mainly for summer grazing for sheep and cattle, in which frost occurs after June 1. The dates of last killing frost vary year by year from the 20-year average date indicated on the map. The insert map (figure 91) shows the dates for one year—1914. In other years the dates and the areas covered may be different. The graph (figure 92) for five representative stations shows, by means of a dot for each year of the record, the dates of occurrence of the last killing frost in spring with reference to the average date for the station.

WEATHER MAPS SHOWING CONDITIONS FAVORABLE FOR FROST

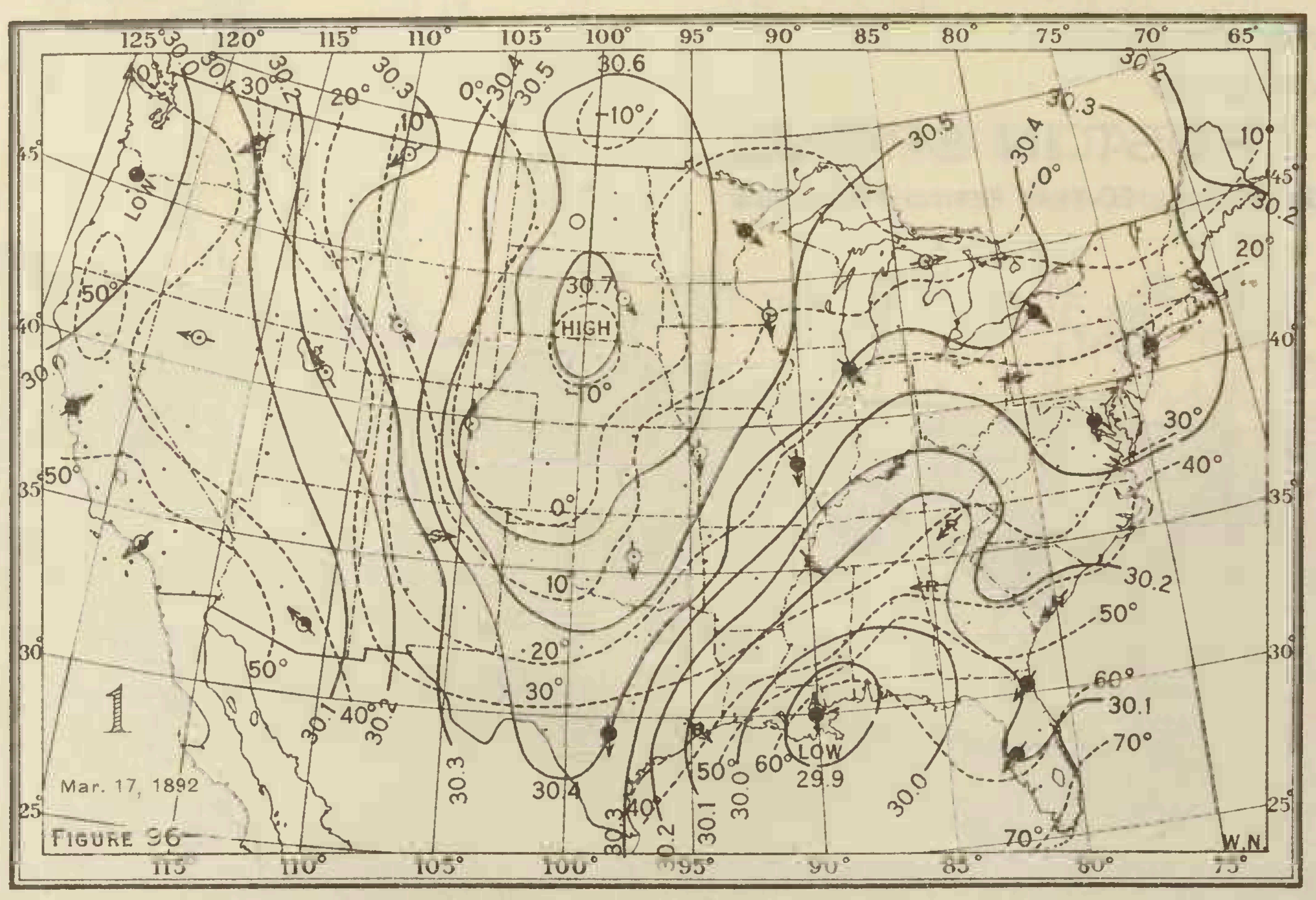
Observations taken at 8 a. m., 75th meridian time. Air pressure reduced to sea level. ISOBARS (continuous lines) pass through points of equal air pressure. ISOTHERMS (dotted lines) pass through points of equal temperature; they are drawn for every 10 degrees. SYMBOLS indicate state of the weather: ○ clear, ◑ partly cloudy, ● cloudy, R rain, S snow. Arrows fly with the wind.

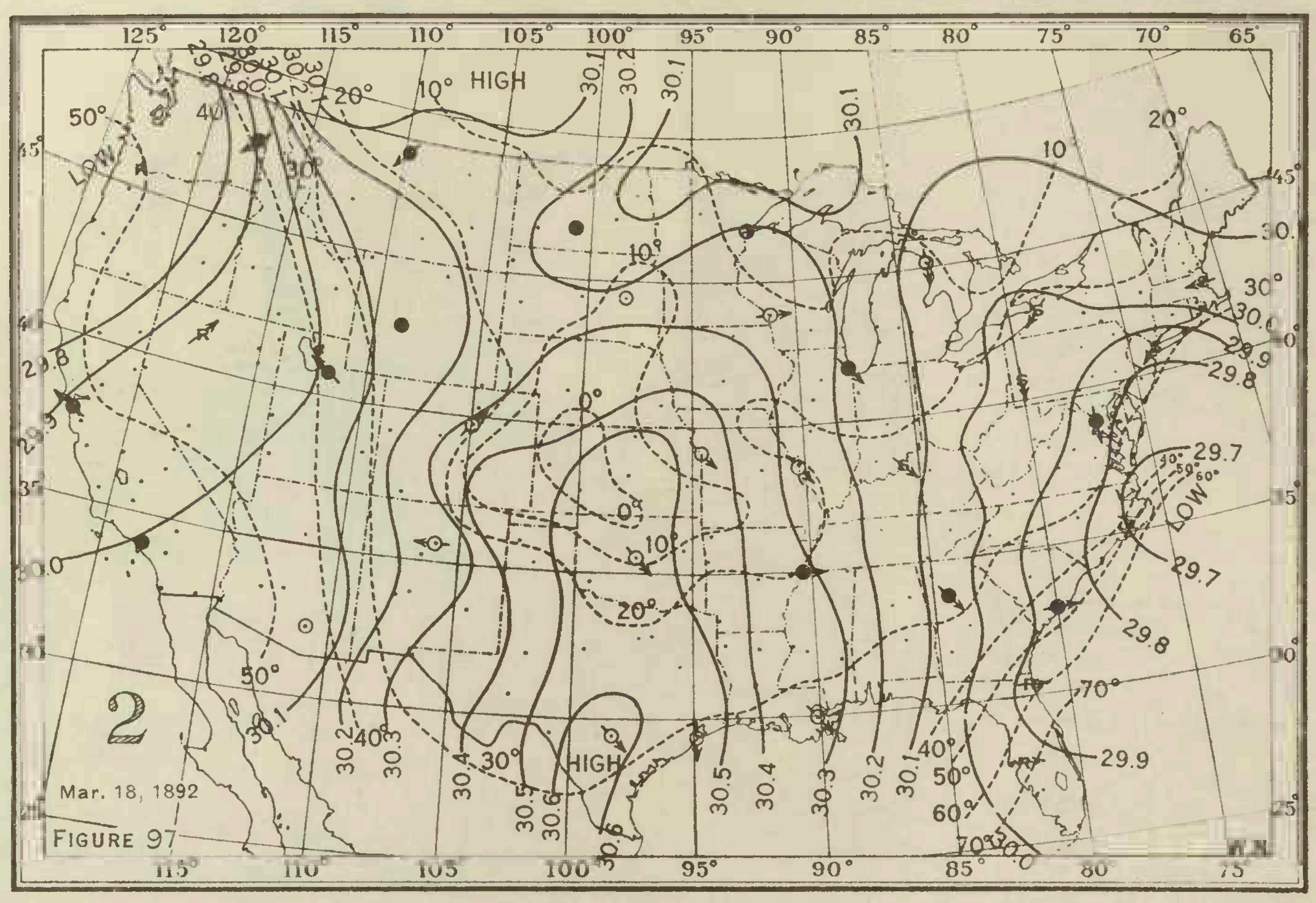


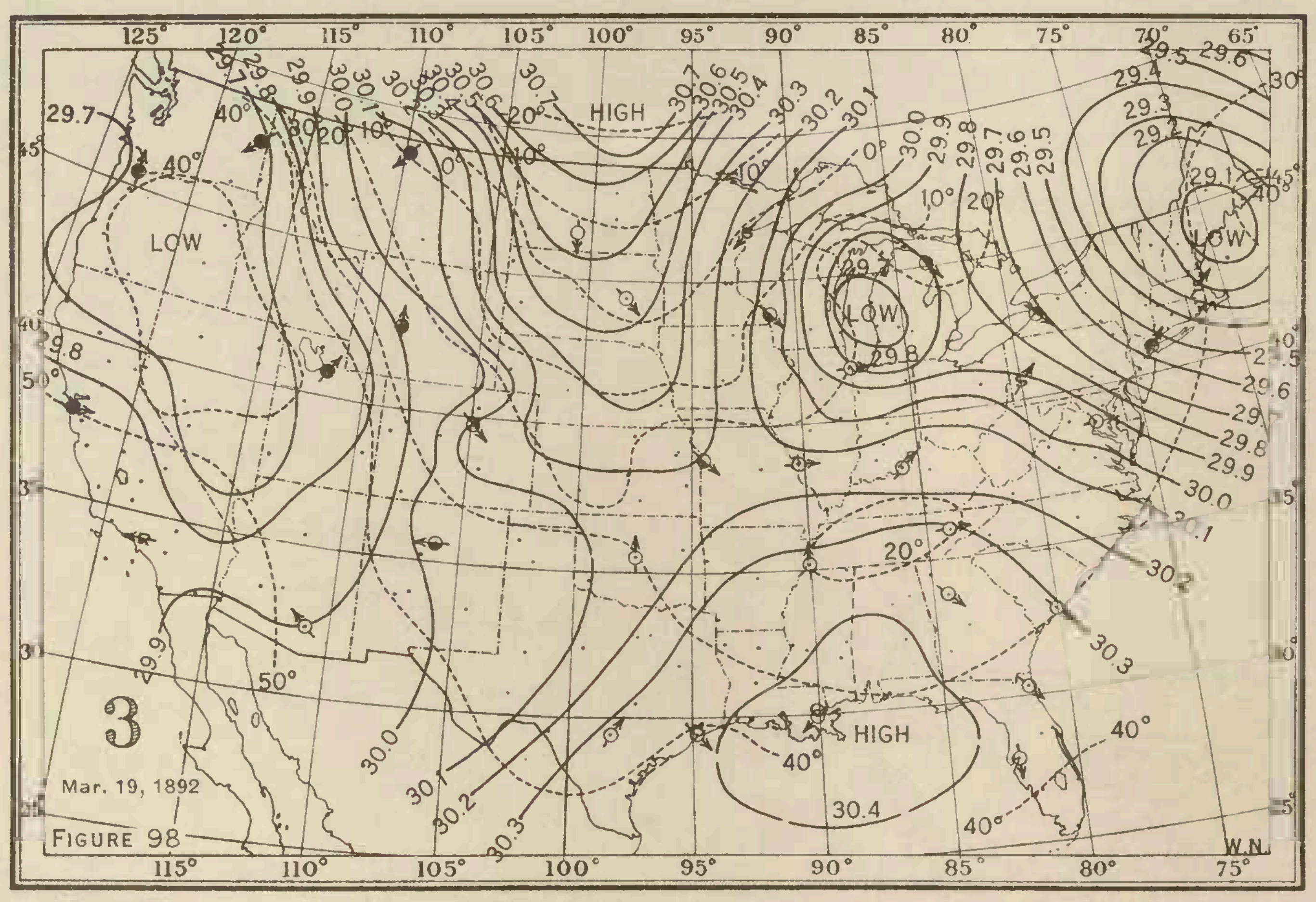




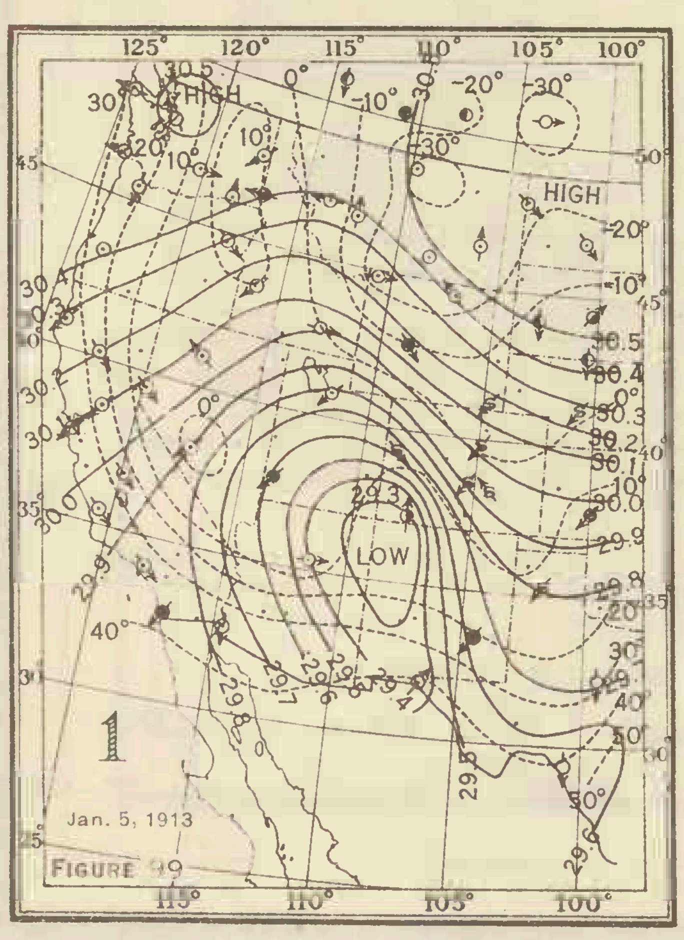
Figures 93, 94, and 95. Severe cold wave and freeze in the Gulf States. Temperatures on the 29th: Mobile 16°, Jacksonville 14°, Tampa 19°, Jupiter 24°, and Key West 44°

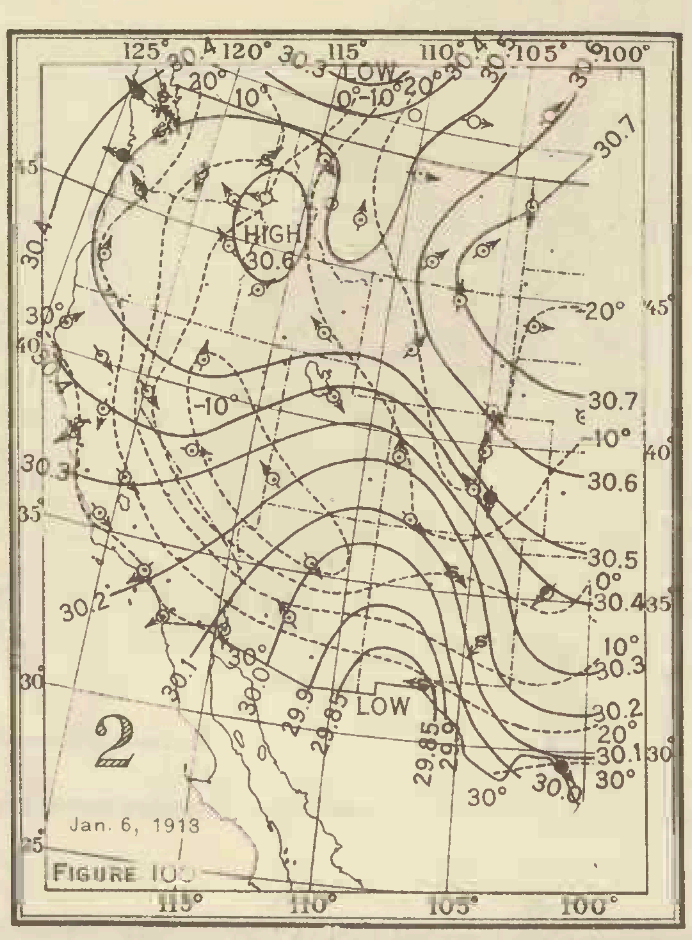


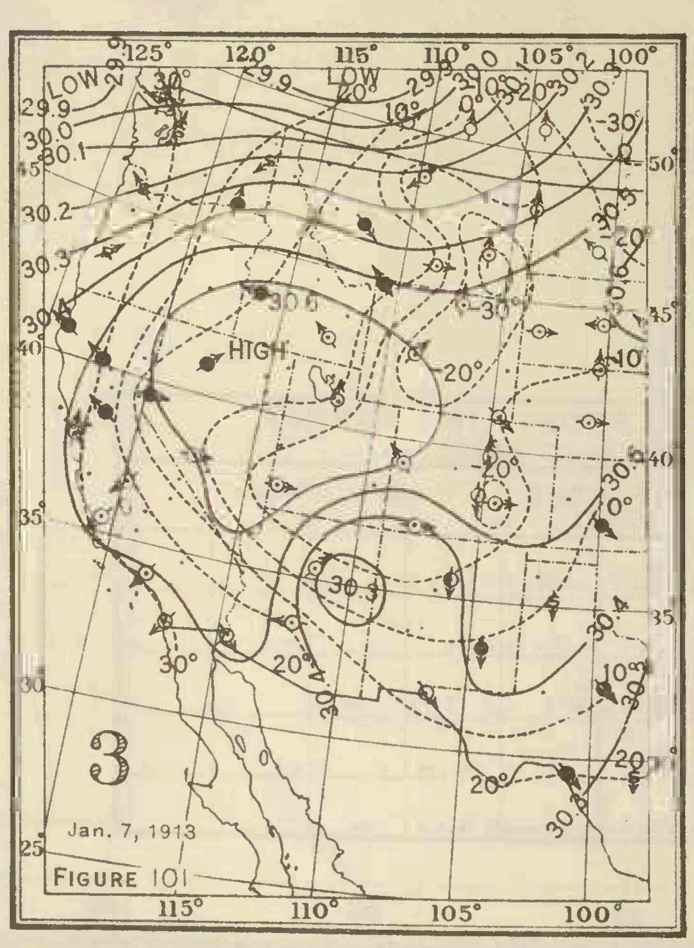


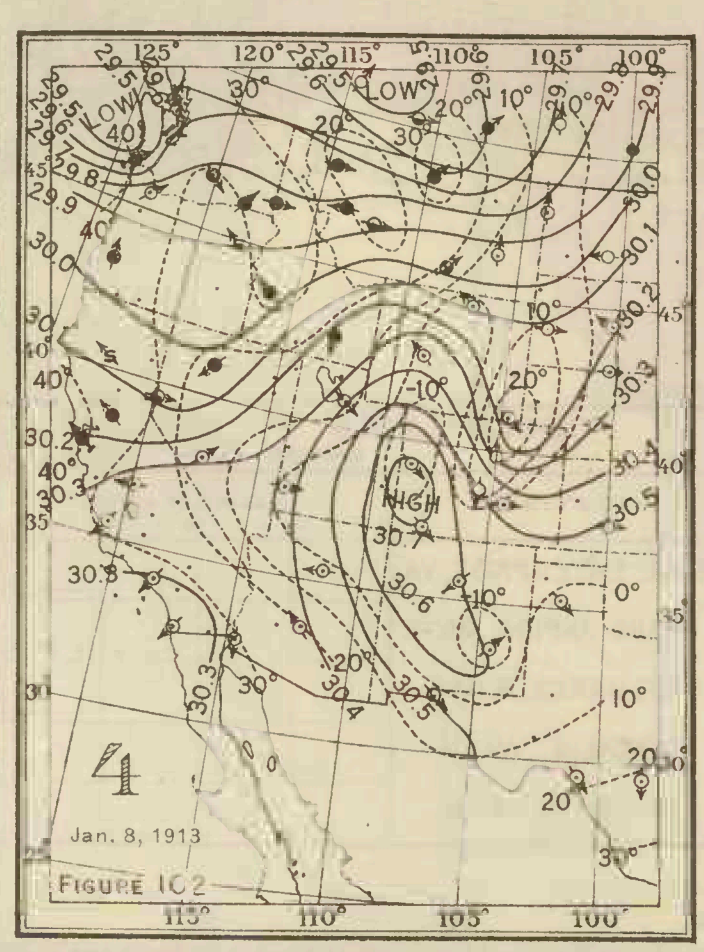


Figures 96, 97, and 98. From the 17th to the 19th low temperatures and frost seriously injured crops and early vegetation from the southeastern slope of the Rocky Mountains over the Gulf and South Atlantic States and the northern half of the Florida Peninsula.









Figures 99, 100, 101, and 102. This pressure distribution is typical for frost in southern California. During the midday hours the temperature did not rise much above 50°. Citrus fruit was subjected to temperatures below freezing for four successive periods averaging 4 hours for the first, 4 hours for the second, 13 hours for the third, and 9 hours for the fourth. The temperature was generally below freezing for a total of 30 hours, below 25° for 12 hours, and below 20° for 2 hours.

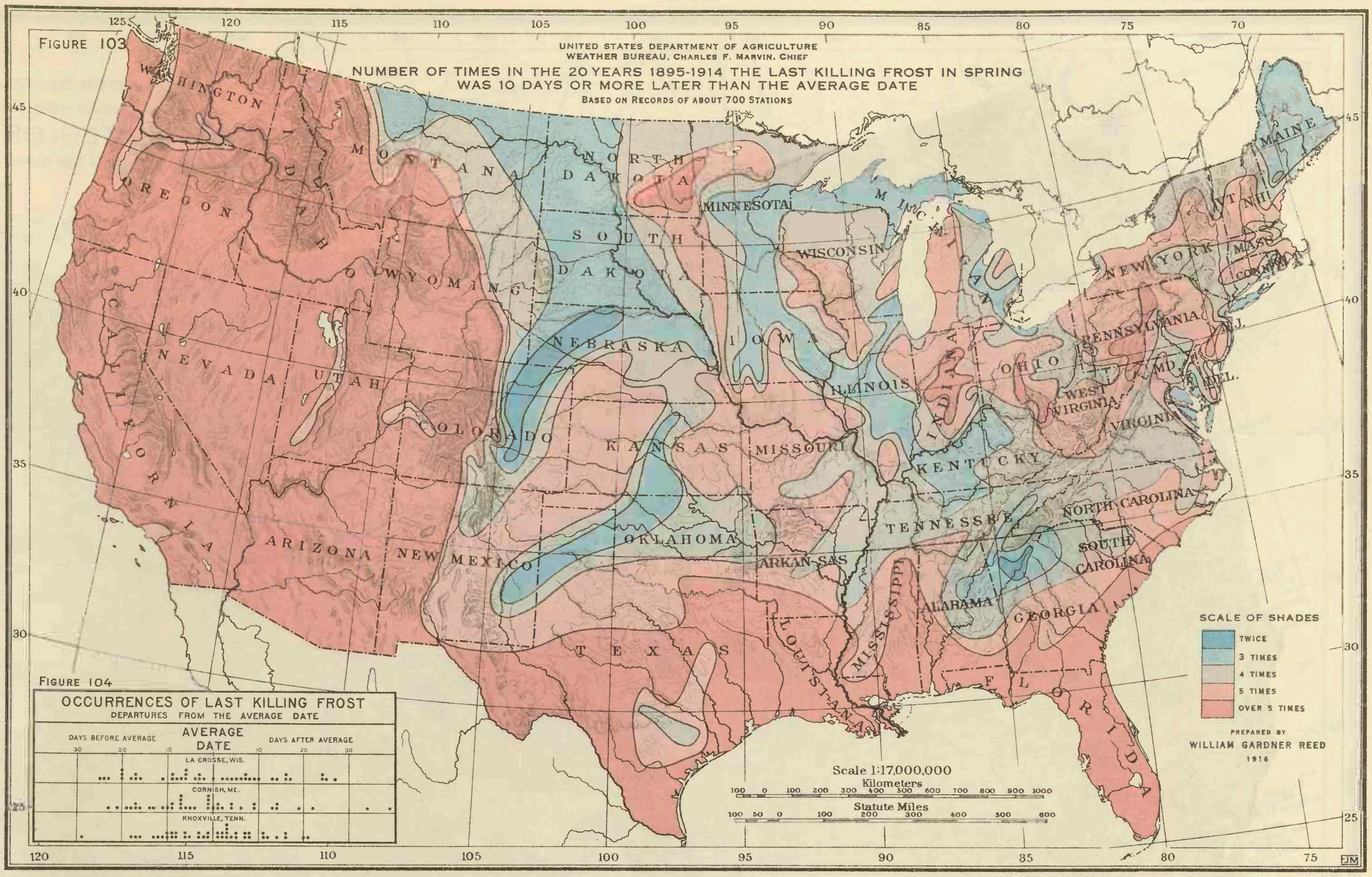
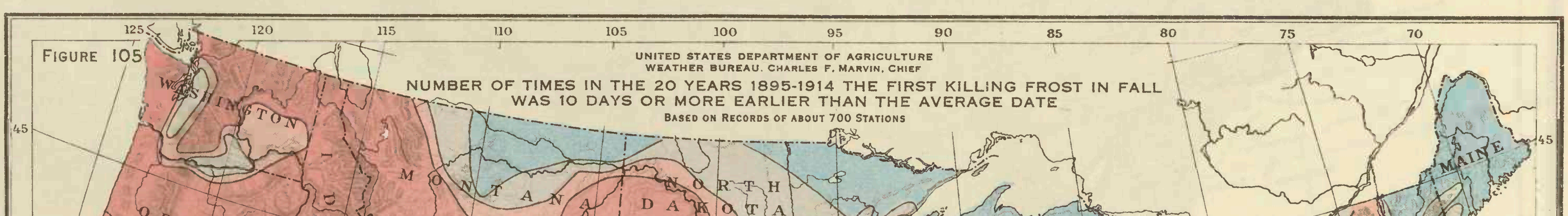


Figure 103. This map shows how many times in the 20 years 1895-1914 the last killing frost in spring has been 10 days or more later than the average date, and indicates the relative dependability of the different portions of the map of average dates of last killing frost in spring (figure 90). The variations are wide in the western part of the country, but owing to the differences in local conditions exact mapping is impracticable. The Gulf States and the portion of the United States west of the Rocky Mountains experience the most frequent variations of considerable amount in the date of last killing frost in spring, while areas in northern Georgia and in eastern Colorado and western Nebraska show the least frequent variations. The graph (figure 104) shows for each year of the record at three representative stations the actual date of the last killing frost in spring with reference to the average date.



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

Figure 105. This map shows how many times in the 20 years 1895-1914 the first killing frost in fall has been 10 days or more earlier than the average date, and indicates the relative dependability of the different portions of the map of average date of first killing frost in fall (figure 107). The most frequent variations of 10 days or more are found in the Western States, southern Texas, Florida, and northwestern Ohio; the least frequent variations in the Texas Panhandle and western Oklahoma and in western Nebraska and southeastern Wyoming. The graph (figure 106) is similar to figure 104 above.

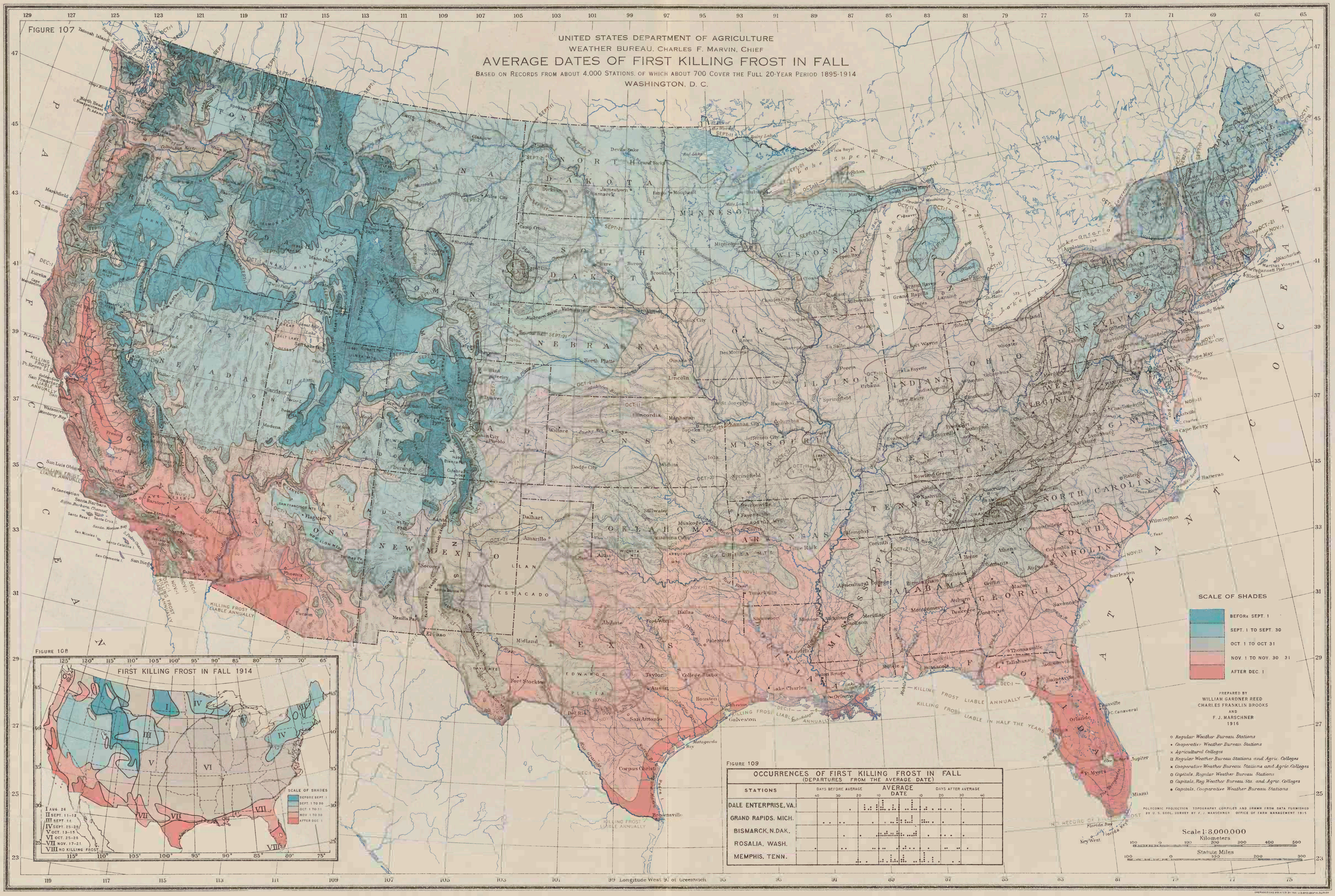


Figure 107 shows the average of the dates on which the first killing frost in fall has occurred. In the East and Middle West the lines are drawn for the 1st, 11th, and 21st of each month; from the Rocky Mountains westward for the 1st of each month only. The only Weather Bureau station in the United States where killing frost does not occur is Key West, Fla. Except for the peninsula of Florida, the coast of the Gulf of Mexico, and favored localities [illegible] Along the northern margin of the cotton belt the first killing frost occurs on the average about October 25, along the northern margin of the corn belt about October 1, and along the northern boundary of the United States early in September. In the higher regions of the West the first killing frost occurs before September 1, in fact, is likely to occur any time during the summer. The dates of last killing frost vary year by year from the 20-year averages indicated on the map. The insert map (figure 108) shows the dates for one year—1914. In other years the dates and the areas covered may be different. The graph (figure 109) for five representative stations shows, by means of a dot for each year of the record, the dates of occurrence of the first killing frost in fall with reference to the average date for the station.

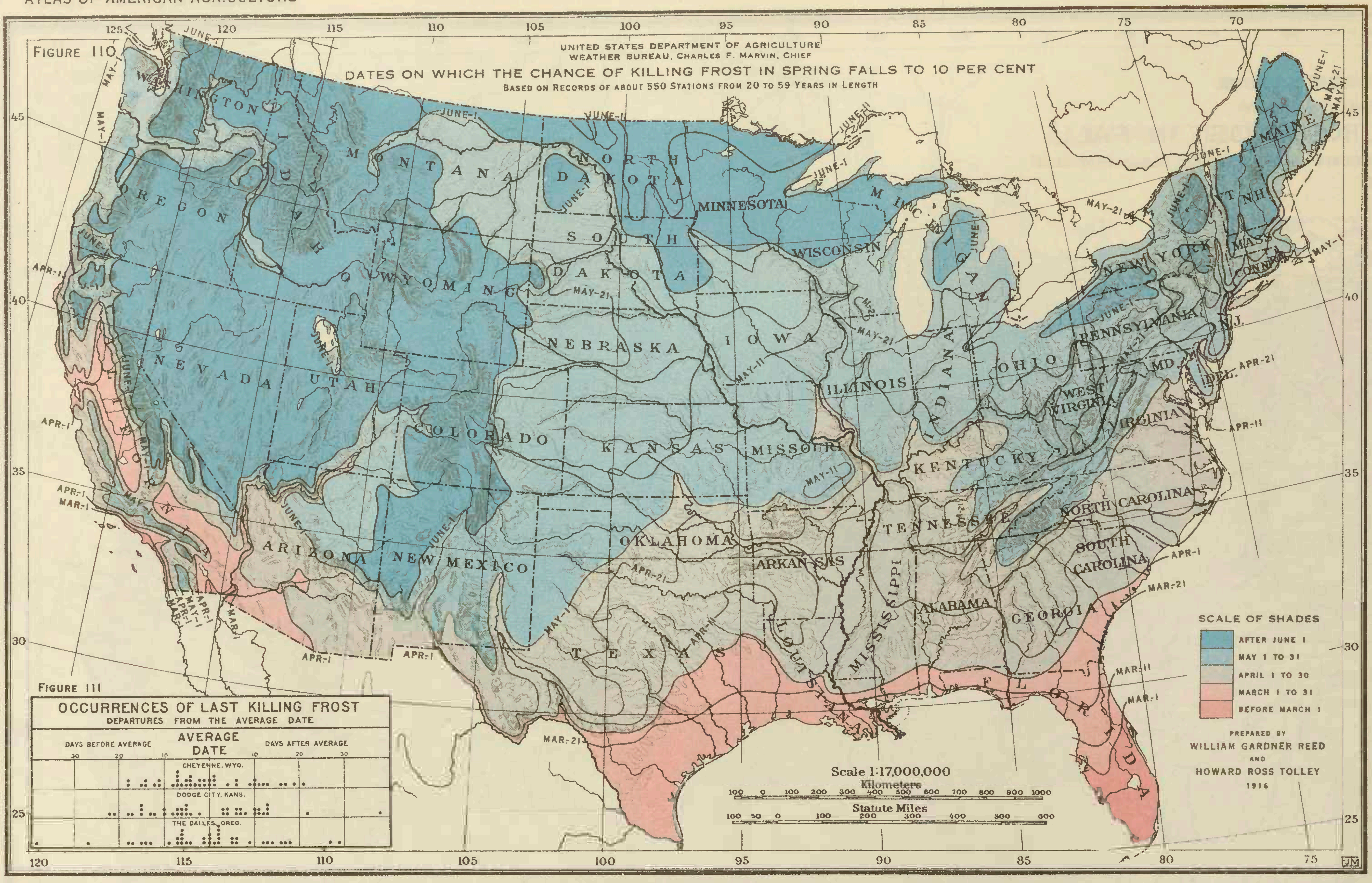


Figure 110. This map shows the dates after which killing frost is likely to occur only one year in ten on the average. Lines have been drawn for the 1st, 11th, and 21st of each month for the East and Middle West, and for the 1st of each month from the Rocky Mountains westward. At Key West, Fla., frost does not occur. The March 1 line crosses the peninsula of Florida, and in the West includes the southwestern portion of Arizona and the coast of southern California. Along the northern margin of the cotton belt only one year in ten is the last killing frost likely to occur as late as April 21, and along the northern margin of the corn belt as late as May 25. Frost occurs later than June 1 in one-tenth of the years along the northern boundary of the country and in the more elevated regions, especially in the West. The graph (figure 111) shows the actual dates of the last killing frost in spring with reference to the average date for each year of the record at three representative stations.

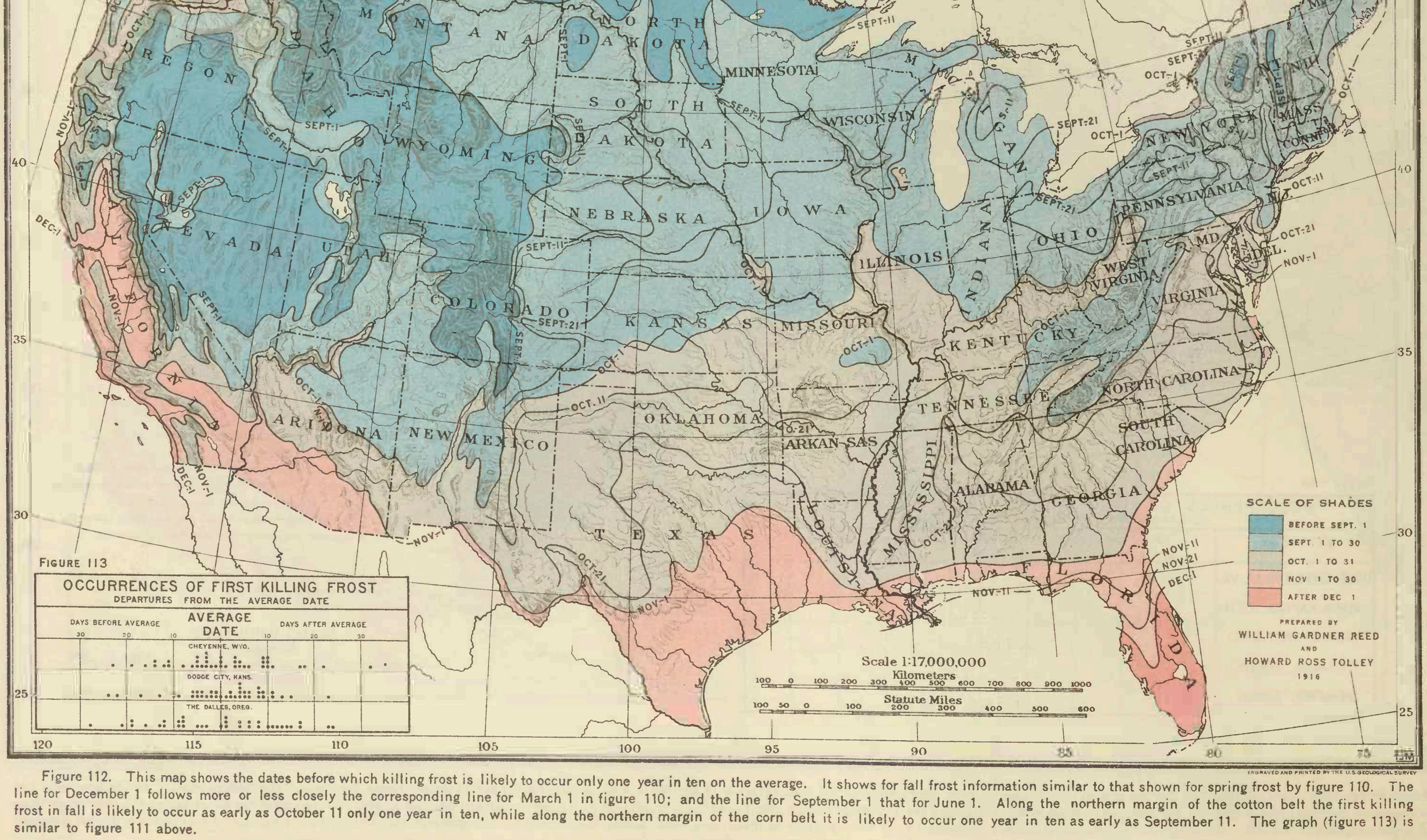


Figure 112. This map shows the dates before which killing frost is likely to occur only one year in ten on the average. It shows for fall frost information similar to that shown for spring frost by figure 110. The line for December 1 follows more or less closely the corresponding line for March 1 in figure 110; and the line for September 1 that for June 1. Along the northern margin of the cotton belt the first killing frost in fall is likely to occur as early as October 11 only one year in ten, while along the northern margin of the corn belt it is likely to occur one year in ten as early as September 11. The graph (figure 113) is similar to figure 111 above.

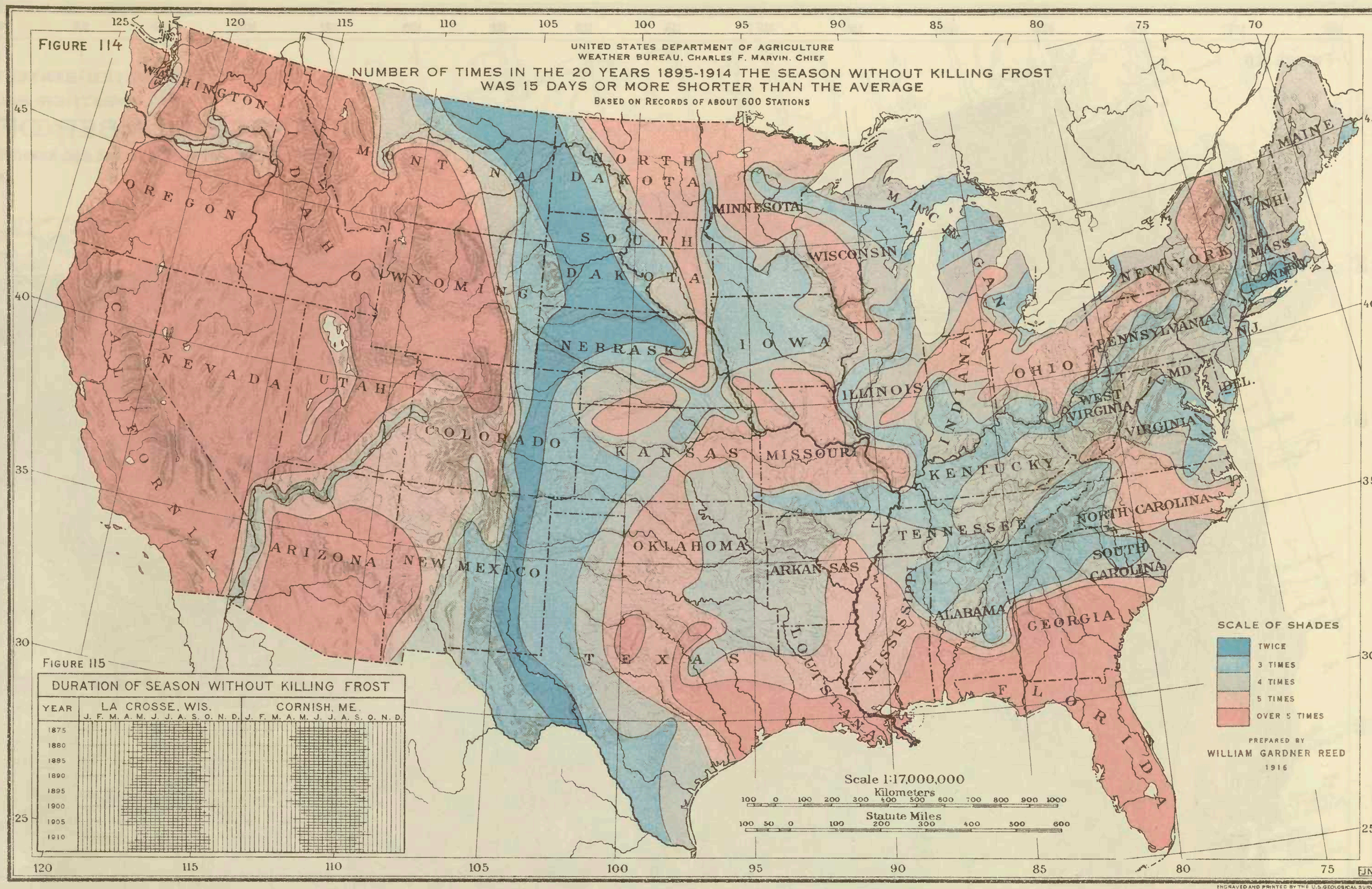


Figure 114. This map shows how many times in the 20 years 1895-1914 the season without killing frost was 15 days or more shorter than the average and indicates the relative dependability of different portions of the map of the average number of days without killing frost (figure 116). The variations are wide in the western part of the country, but owing to differences in local conditions exact mapping is impracticable. The portion of the United States west of the Rocky Mountains and the Gulf and South Atlantic coasts experience the most frequent variations of two weeks or more in the length of the season without killing frost, while the Great Plains area experiences least frequently variations of this amount. The graph (figure 115) shows the actual length of the period without killing frost for each year of the record at two representative stations.

southern half of the Florida Peninsula, the immediate coast of the Gulf of Mexico, and that of southern California. Killing frost occurs in fewer than half the winters only in southern Florida and the region around San Diego, Cal. With the exception of Key West and some of the neighboring keys, frost has occurred in all parts of the United States; and over by far the greater portion of the country it is practically certain to occur every year.

In places along the northern boundary of the United States and at the higher altitudes in the western part of the country the average date of last killing frost in spring is later than June 1; this area includes about one-eighth of the whole country. A large portion of the western United States is included in this area, but in some localities within this region frost conditions are much more favorable for agricultural work.

Variations in the Dates of Spring Frost.—In order to show how far the average dates represent the frost conditions which actually occur, some statement of the variations is necessary. It is, however, not possible to state this additional information with the same degree of accuracy as that for the average dates because of the much smaller number of records of sufficient length to give significant results. Figure 103, based on about 700 records, shows the number of times in the 20 years 1895–1914, the last killing frost in spring was 10 days or more later than the average date. This map may be regarded as a measure of the variability of the dates of last killing frost; it shows for the whole country some of the information which is given by the diagrams of dispersions of frost dates (figs. 88, 92, 104 and 111). The variations are found in general to be smaller near the Atlantic Coast and in the strip of the country just east of the Rocky Mountains. The greatest variations are those in the section west of the Rocky Mountains and also in the regions where frost is less common, particularly in Florida and along the Gulf Coast. Frosts are more common in the valley bottoms than on the lower slopes, but the depths to which the valleys fill with cold air differ from time to time and from place to place, so that stations on the lower slopes are subject to widely varying frost conditions. The greater variations in the West should be taken into account in using frost maps of this portion of the country. Variations in dates of last killing frost are of little significance where frost is not of annual occurrence—that is, in Florida, along the Gulf Coast, and in portions of California and Arizona—because in these regions the type of agriculture is such that the occurrence of any frost is dangerous and proper protection of plants depends more upon timely warnings than upon general statements of the time of year in which frosts may be expected.

The security from damage by frost is indicated by figure 110, which shows the dates on which the probability of frost falls to 10 per cent. This map is similar to figure 90, except that it shows the conditions somewhat less accurately because of the smaller number of stations available (about 600 as against 4,000 for the large map). The lines showing these dates have been drawn for the same intervals as those in figure 90—that is, for the 1st, 11th, and 21st of each month east of the Rocky Mountains, and for the 1st of each month to the westward. The line showing when the chance of killing frost is 10 per cent or less on March 1 corresponds more or less with the line of annual occurrence of killing frost. In the West, in Florida, and along the Gulf Coast the chance of killing frost falls to 10 per cent about 30 days later than the average date of last killing frost in spring. In other portions of the country the difference is smaller, but is commonly not less than 10 days. The areas in which the chance of spring frost is greater than 10 per cent on June 1 include the region along the northern boundary of the United States, elevated areas in the Appalachian Mountains, and the greater part of the higher altitudes of the West.

Average Dates of First Killing Frost in Fall.—The average dates of first killing frost in fall are shown by figure 107, which is based on records for the same stations as were used in preparing figure 90. The regions which are not subject to annual frost are, of course, the same on both maps. The area for which the average dates of first killing frost are earlier than September 1 is much the same as that for which the average dates of last killing frost in spring are later than June 1, although somewhat smaller in extent. Throughout both maps the general similarity is striking, the differences being mainly those of detail.

Variations in the Dates of Fall Frost.—Figures 105 and 112 for fall frosts are similar to figures 103 and 107 for spring frosts. The differences in the variations of the dates of spring and fall frosts are small; the features shown by the maps are, therefore, much the same, although they differ in detail.

Average "Growing Season."—Figure 116 shows the length of the period between the average date of last killing frost in spring (fig. 90) and the average date of first killing frost in fall (fig. 107). The lines have been drawn for 10-day intervals in the eastern and central United States and for 30-day intervals in the West. The length of the period varies from 365 days at Key West, Fla., to considerably less than 90 days in the extreme northern portion of the country and the more elevated portions of the West. The large area in which the average length of the period without killing frost is less than 90 days is an important feature of this map and is essentially the same as that in which the average dates of last killing frost are later than June 1 and those of first killing frost earlier than September 1. The region is, for the most part, not available for general farming; where the rainfall is sufficient it is mostly forested.

Variations in Length of Growing Season.—Figure 114 shows how many times in the 20 years 1895–1914 the period without killing frost was 15 days or more shorter than the average. It was prepared from a simple count of the years in which the number of days between last killing frost in spring and first killing frost in fall was 15 days or more shorter than the average. In many years the period was less than 15 days shorter than the average, but as it began before the date of last killing frost this portion can not be considered available. The general features are similar to those shown by figures 103 and 105. It may be regarded as an indication of the variability of the season without frost in different parts of the country. It shows for the whole country information similar to that given for selected stations by figures 88, 115, 118, and 120.

Figure 32 shows the number of days available for plant growth in about four-fifths of the years. The intervals between the lines are the same as in figure 29—that is, 10 days in the East and 30 days in the West. However, the records are not of sufficient length to justify mapping on a scale as large as that of the double-page map any data for the growing season other than

FIGURE 116

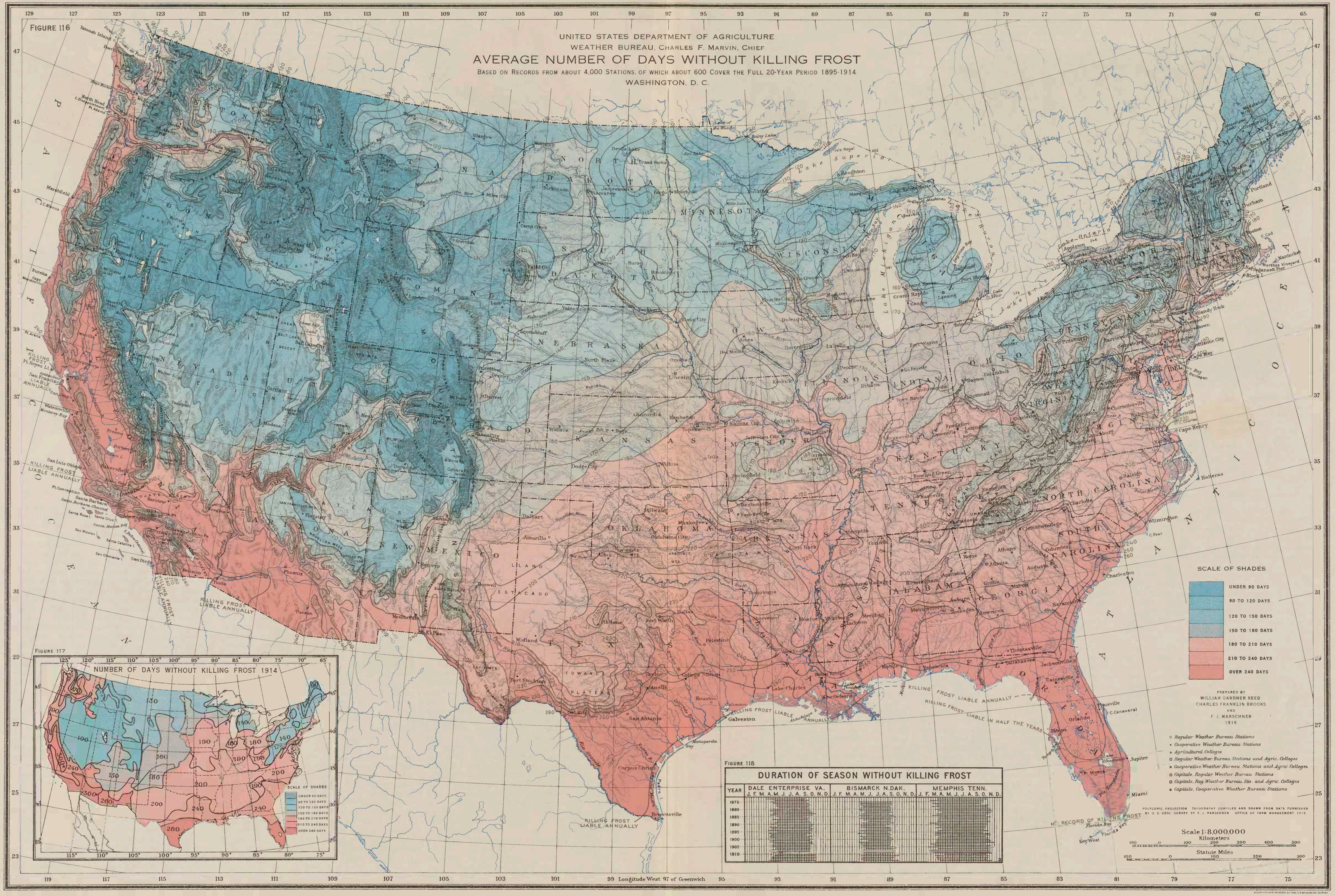


Figure 116 shows the average length of the season without killing frost for the period 1895-1914. In the East and Middle West the lines are drawn for 10-day intervals; from the Rocky Mountains westward for 30-day intervals only. At Key West, Fla., the frostless season covers the whole year. Throughout most of Florida, along the coast of the Gulf of Mexico, and in favored localities in Arizona and California, the average season without killing frost is more than 260 days. Along the northern margin of the cotton belt it is about 200 days, along the northern margin of the corn belt from 140 to 150 days, in northern Maine and northern Minnesota, where hay, potatoes, oats, and barley are the principal crops, it is about 100 days, and in the higher regions of the West it is less than 90 days. There is very little agriculture, except that based upon wild hay and grazing, where the average season between killing frost is less than 90 days. In such regions frosts are likely to occur in any of the summer months. The length of the season without killing frost varies year by year from the 20-year average indicated on the map. The insert map (figure 117) shows the length of the period without killing frost in one year—1914. These periods may be of different length and the areas of different extent in other years. The graph (figure 118) shows the length of the season at three representative stations for each year of the record.

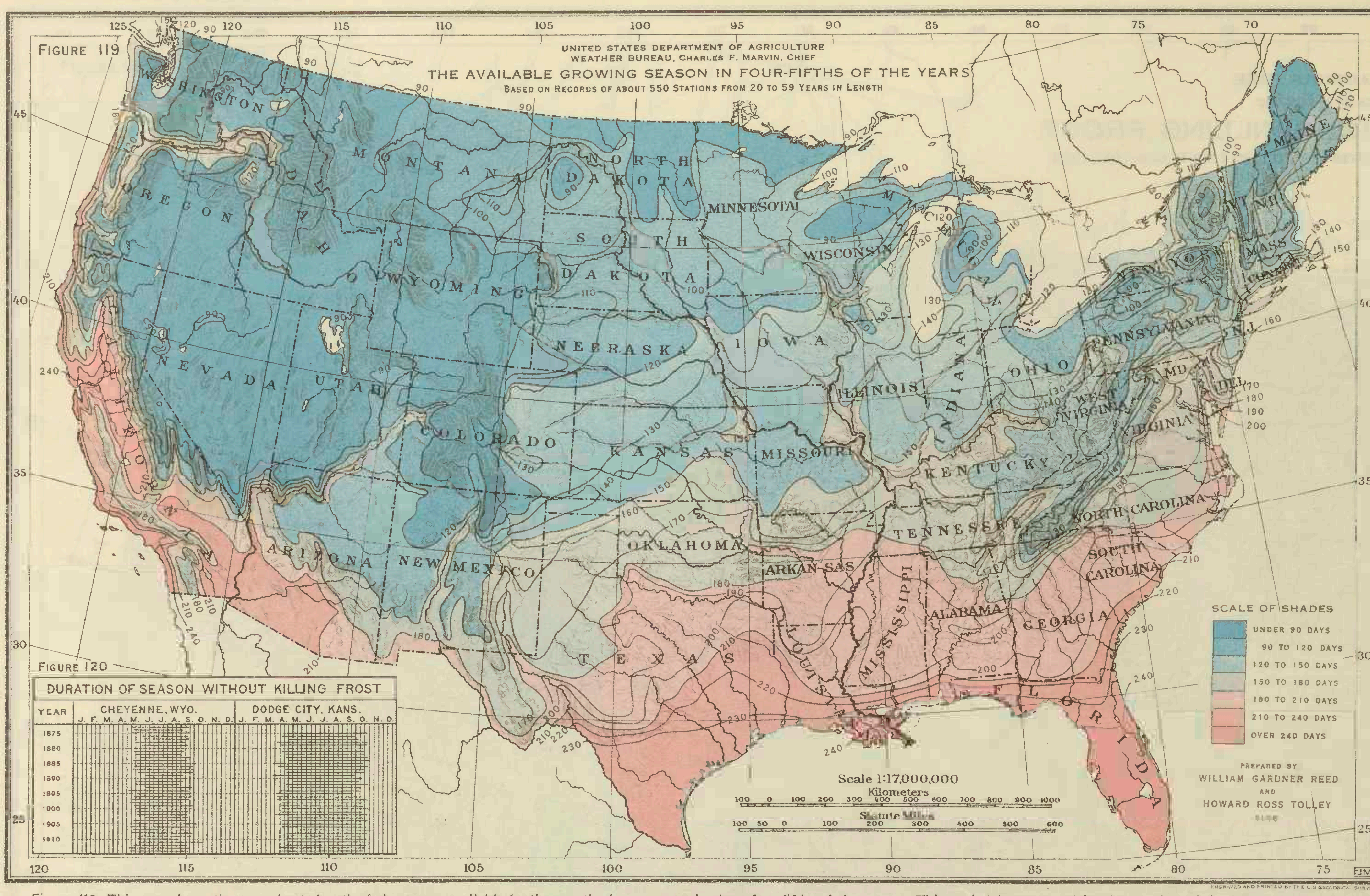


Figure 119. This map shows the approximate length of the season available for the growth of many crops in about four-fifths of the years. This period is measured by the number of days between the date on which the chance of spring frost falls to 10 per cent and that on which the chance of fall frost rises to 10 per cent. Lines have been drawn for 10-day intervals in the East and Middle West and for 30-day intervals from the Rocky Mountains westward. In the southern part of Florida and of Louisiana and in parts of California this available growing season is 240 days or more; in northern Maine, northern Minnesota, and North Dakota, and in the more elevated regions, especially in the West, it is less than 90 days. The graph (figure 120) shows for two representative stations the actual length of the period without killing frost for each year of the record.

the average length of the period without killing frost. The length of the season shown by figure 119 varies from 15 days shorter than the average period without killing frost in some localities to 50 days shorter in others. The differences between the two maps are greatest in those regions where departures of 15 days or more (see fig. 114) are most numerous. In the regions having 90 days or less without frost in four years out of five general farming is limited largely to small grains, grasses, and potatoes, and in general the area is much the same as that in which the average period without killing frost is less than 90 days, although of course somewhat greater in extent. The longest safe growing season is found in the states bordering the Gulf of Mexico, in southern Arizona, and portions of California. The safe growing season in the eastern United States varies from about 240 days along the Gulf of Mexico to 100 days or less in Minnesota and the Dakotas, and 90 days or less in parts of the Appalachian Mountains and the higher altitudes in New York and New England. In the more elevated regions of the West the safe season is less than 90 days. This map represents in general the number of days expected to be available for the growth of crops in a sufficiently large proportion of the years to enable the organization of farm enterprises on that basis with a reasonable chance of success.

Suitable Planting Dates.—It is essential that crops be planted late enough to be safe from too great risk of spring frost and at the same time early enough to permit maturity before the risk from fall frost becomes too great. When the selection of planting dates is made, the chance of damage by spring frost, the advantages of maturity for early markets, and the length of the growing period of the crop must all be considered. In the intelligent selection of planting dates the additional profits from early maturity must be weighed against the possibilities of loss from spring frost, and in regions where the growing period of the crop is such that fall frost may result in damage before maturity, planting dates should be selected which will give a reasonable chance of safety in the spring and also in the fall. Greater risks can also be taken at least on a part of the crop where the cost of replanting is comparatively small and the profits from early marketing are considerable.

The risk of frost may be determined mathematically if the record is of sufficient length. From a study of the long records in the United States it appears that any record of more than 20 years may be used as a basis for such computation. There are in the United States records of about 600 stations, which are suitable for this purpose. A study of general farming conditions has led to the conclusion that, for many crops, profit in the long run will result if crops are lost by spring frost in not more than 10 per cent of the years. In other words, the date when the frost risk falls to 10 per cent appears a reasonable time for planting certain crops, especially those sensitive to frost. Figure 110 shows the dates upon which the frost risk falls to 10 per cent. A crop which is not in a condition to be damaged by killing frost before the dates shown by figure 110 (for example, at Peoria, April 29) will be safe 9 years in 10 on the average. This means that only 10 years in a century will have killing frost after that date and not that one year in each decade is subject to killing frost after April 29. On this scale only the general conditions over wide areas can be shown, and the records must be consulted for information in regard to particular places. In general, the date upon which the chance of loss becomes small enough to justify the risk of planting is in different sections of the country from 10 to 30 days later than the average date of last killing frost.

Suitable Harvest Dates.—The amount of risk which can be assumed in fall does not differ greatly from that which can be assumed in spring, and the risk may be computed in the same manner. Figure 112 shows the dates upon which the chance of killing frost in fall rises to 10 per cent, which for Peoria is October 6. After this date there are fewer than nine chances of safety in ten. These dates are from 10 to 30 days earlier than the average date, the difference between the two dates for any station being about the same as the difference between the similar dates in spring.

The Season Available for Plant Growth.—The number of days available for plant growth is an important factor in determining the availability of any region for a particular crop. The length of this growing season is conveniently stated in the number of days free from killing frost, although the length of the day, the amount of sunshine, and probably other factors tend to modify the period required. Even when the length of the growing season and the total amount of heat received are sufficient, it does not necessarily follow that crops will mature, as favorable temperatures during critical periods of growth are necessary for normal plant development. The three factors—length of growing season, total heat, and temperatures reached—operate on plant development more or less independently. As in the case of frost dates, some method of summarizing the period without killing frost must be adopted when more than a very small number of places are considered at one time. Figure 116 is a map of the average number of days without killing frost for the United States. Crops in a condition to be damaged on the average date of last killing frost in spring will be lost in half the years, but half of those surviving spring frost, and not harvested until the average date of first killing frost in fall, will be lost by fall frost. Therefore, for crops requiring the full length of the season to mature, the average period without killing frost is available to the farmer in only about one-fourth the years.

If a region is to be regarded as available for a particular crop, loss from spring and fall frosts must not occur frequently enough to consume the profits of the years without such losses. The results of the studies of the chance of killing frost in spring and fall provide a method of determining the chance of a growing season of any given length. For example, if the chance of safety from frost after a certain date in spring is 90 per cent, and if the chance of safety from frost before another certain date in fall is also 90 per cent, then the chance that the period between these two dates will be free from killing frost in any given year is 81 per cent. This means that, in the long run, frost damage would not occur in this period four years in five. This may be regarded as the season safely available for the growth of many planted crops; it is shown by figure 119. The number of days indicated by the map is the period after the dates shown by figure 110 which will be free from killing frost in about four-fifths of the years. In general the length of period in which the chance of killing frost is small enough to permit profitable agriculture is, depending on the locality, between 15 and 50 days less than the average number of days without killing frost.

William Gardner Reed.

Issued March 15, 1922

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

ATLAS
OF
AMERICAN AGRICULTURE

Prepared under the Supervision of O. E. BAKER, Agriculturist
Office of Farm Management, H. C. TAYLOR, Chief

CLIMATE

Contribution from the U. S. Weather Bureau, CHARLES F. MARVIN, Chief

PRECIPITATION AND HUMIDITY

Prepared under the Direction of P. C. DAY, Climatologist

BY

J. B. KINCER
Meteorologist, U. S. Weather Bureau

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

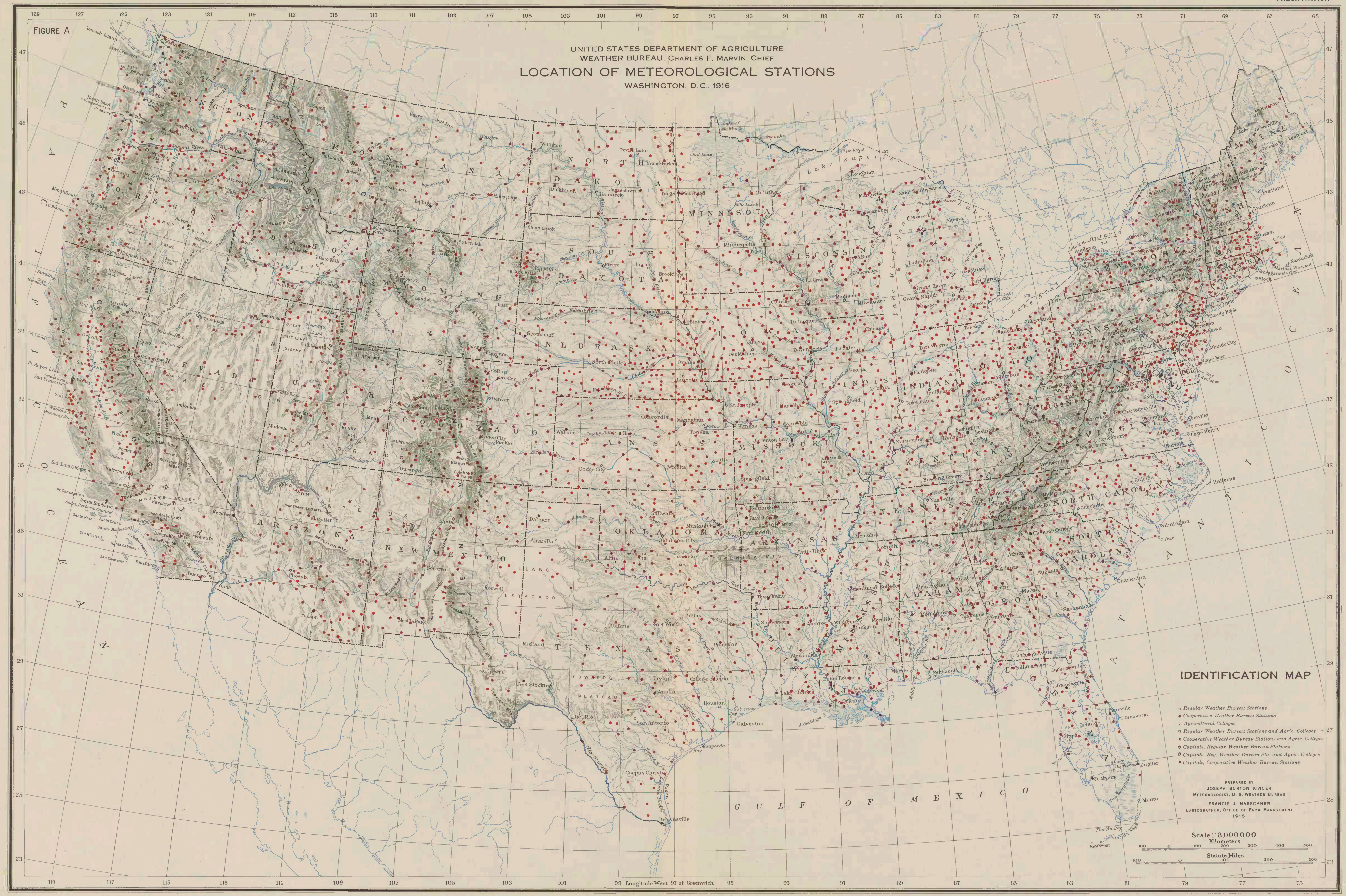


Figure A.—This map shows the location and relative density in different sections of the country of the Weather Bureau stations whose records were compiled and used in the preparation of all of the precipitation maps, except where otherwise specified. The location of the 200 regular, full-reporting Weather Bureau stations, whose records were used in the preparation of figures 56, 59, 70, 75, 77, 79, 80, 81, 82, 83, and 84, is shown by a hollow circle. The location of the cooperative stations, whose records were used in addition to those of the regular Weather Bureau stations in the preparation of the annual, seasonal, and monthly precipitation maps and the snowfall map, is shown by a red dot. The more important mountain ranges and river valleys are also shown on this map by means of hachuring. These physiographic features exercise an important influence over the distribution of precipitation.

SELECTED REFERENCES.

Abbe, Cleveland: Determination of the True Amount of Precipitation and its Bearing on Theories of Forest Influences. U. S. Dept. Agr., Div. Forestry Bul. 7, append. I (p. 175–186), incl. tables. 1893. Reprinted in part as The Rain Gage and the Wind. Mo. Weather Rev., vol. 27, p. 464–468. Washington, 1899.

Alexander, William H.: Distribution of Thunderstorms in the United States. Mo. Weather Rev., vol. 43, p. 322–340, incl. tables, pls. 71–83. 1915.

Beals, Edward A.: Rainfall and Irrigation. U. S. Dept. Agr., Yearbook, 1902, p. 627–642, figs, 49–54, 1903.

Beals, Edward A.: Variations in Rainfall. Mo. Weather Rev., vol. 39, p. 1448–1452, incl. tables, 1 fig. 1911.

Bigelow, Frank H.: Storms, Storm Tracks, and Weather Forecasting. U. S. Weather Bur. Bul. 20, 87 p., incl. tables, 20 charts. Washington, 1897.

Binnie, Alexander R.: Rainfall Reservoirs and Water Supply. xi + 157 p., incl. tables, 56 pls. New York, Van Nostrand, 1913.

Birkinbine, Carl Peter: Variations in Precipitation as Affecting Water Works Engineering [with Discussion]. Journ. Am. Water Works Assoc., vol. 3, p. 1–103, incl. tables, maps, diagr. Baltimore, 1916.

Blair, Thomas A.: A Statistical Study of Weather Factors Affecting the Yield of Winter Wheat in Ohio. Mo. Weather Rev., vol. 47, p. 841–847. 1919.

Bowie, Edward H., & Weightman, R. Hanson: Types of Anticyclones in the United States and their Average Movements. Mo. Weather Rev., Suppl. no. 4, 25 p., incl. tables, 73 charts. 1917.

Bowie, Edward H., & Weightman, R. Hanson.: Types of Storms in the United States and their Average Movements. Mo. Weather Rev., Suppl. no. 1, 37 p., incl. tables, 114 charts. 1914.

Brandenburg, F. H.: The Relation of Weather to the Flow of Streams. Mo. Weather Rev., vol. 34, p. 405–406. 1906.

Briggs, Lyman J., & Belz, J. O.: Dry Farming in Relation to Rainfall and Evaporation. U. S. Dept. Agr., Bur. Plant Ind. Bul. 188. 71 p., incl. 6 tables, 23 figs., 1 pl. 1910.

Briggs, Lyman J., & Shantz, H. L.: Relative Water Requirements of Plants. U. S. Dept. Agr., Journ. Agr. Research, vol. 3, p. 1–64, incl. 34 tables, 1 fig., pls. 1–7. 1914.

Briggs, Lyman J., & Shantz, H. L.: The Water Requirement of Plants. I. Investigations in the Great Plains in 1910 and 1911. U. S. Dept. Agr.. Bur. Plant Ind. Bul. 284. 49 p., incl. 21 tables, 2 figs.. 11 pls. 1913. II. A Review of Literature. Bur. Plant Ind. Bul. 285. 96 p., incl. 76 tables, 6 figs. 1913.

Brooks, Charles F.: New England Snowfall. Mo. Weather Rev., vol. 45, p. 271–285, 30 figs. 1917.

Brooks, Charles F.: The Snowfall of the Eastern United States. Mo. Weather Rev., vol. 43, p. 2–11, incl. tables, 13 figs., charts 9–23. 1915.

Brooks, Charles F.: The Snowfall of the United States. Quart. Journ. Roy. Meteorol. Soc., vol. 39, p. 81–86, incl. table, pl. 2. London, 1913.

Carpenter, L. G.: Forests and Snow. Colorado Agr. Exp. Sta. Bul. 55, 12 p., incl. 7 figs., 18 pls. Fort Collins, 1901.

Chittenden, M. H.: Discussion on Floods and Flood Prevention. Proc. Am. Soc. C. E., vol. 42, p. 797–812. New York, 1916.

Church J. E., jr.: Recent Studies of Snow in the United States. Quart. Journ. Roy. Meteorol. Soc., vol. 40, p. 43–52, incl. tables, 6 figs. London, 1914.

Church, J. E., jr.: Snow Surveying—Its Problems and Their Solution. Second Pan American Scientific Cong., Proc., vol. 2. Washington, 1917.

Clayton, H. Helm: The Influence of Rainfall on Commerce and Politics. Pop. Sci. Mo., vol. 60, p. 158–166, incl. table. New York, 1901.

Clayton, H. Helm: Relation between Rainfall and Synoptic Winds. Mo. Weather Rev., vol. 44, p. 80–81, charts 22–24. 1916.

Clayton, H. Helm: Relations of Clouds to Rainfall. In Discussion of the Cloud Observations . . . at Blue Hill Meteorological Observatory. Annals, Harvard Col. Observ., vol. 30, p. 358–365, incl. tables. Cambridge, Mass., 1896.

Day, Preston C.: Relative Humidity and Vapor Pressure over the United States, including a Discussion of Data from Recording Hair Hygrometers. Mo. Weather Rev., Supplement 6, May, 1917.

Fassig, Oliver Lanard: The Climate and Weather of Baltimore. Maryland Weather Service, Special Publ. vol. 2, 515 p., incl. tables, 170 figs., 24 pls. Baltimore, 1907.

Gannett, Henry: Distribution of Rainfall in the United States. U. S. Geol. Surv., Water Supply Paper 234, p. 7–9, 2 maps. 1909.

Gannett, Henry & Others: Rainfall Charts and Rainfall. (36 papers by various authors.) Mo. Weather Rev., vol. 30, p. 205–243, incl. tables, 1 fig., pls. 39–41. 1902.

Goodnough, X. H.: Rainfall in New England. Journ. New England Water Works Assoc., vol. 29, p. 237–438, incl. tables, diagr., pls. 22–24. Boston, 1915.

Greeley, A. W., & Glassford, W. A.: The Climatology of the Arid Regions of the United States. 51st Congress, 2nd session, House Ex. Doc. 287, 356 p. incl. tables, 6 diagr., 37 maps. 1891.

Hallenbeck, Cleve: Precipitation over the Southeast Rocky Mountain Slope. Mo. Weather Rev., vol. 44, p. 341–342, incl. tables, charts 72–76. 1916.

Harrington, Mark W.: Rainfall and Snow in the United States . . . U. S. Weather Bur., Bul. C, 80 p. incl. tables, diagr., with Atlas of 23 pls. 1894.

Hellman, Gustav: Über die Konstruktion von Regenkarten. Bericht über die Tätigkeit K. preuss. Meteorol, Institut, 1914, Anhang p. (1)–(10), incl. tables. Berlin, Behrend & Co., 1915.

Henry, Alfred J.: Rainfall of the United States. U. S. Weather Bur. Bul. D. 58 p., incl. tables, 11 charts, 3 pls. 1897. *Also in* Rept. of the Chief U. S. Weather Bur., 1896–97, p. 315–368. 1897.

Henry, Alfred J.: Secular Variations of Precipitation in the United States. Bul. Am. Geog. Soc., vol. 46, p. 192–201, incl. table, 3 figs. New York, 1914.

Henry, Alfred J.: Normal Precipitation in the Region of the Great Lakes. Mo. Weather Rev., vol. 27, p. 151–153. 1899.

Horton, R. E.: The Melting of Snow. Mo. Weather Rev., vol. 43, p. 599–605, incl. 6 figs. 1915.

Humphreys, W. J.: The Thunderstorm and its Phenomena. Mo. Weather Rev., vol. 42, p. 348–380, incl. 28 figs. 1914. *Also in* Journ. Franklin Inst., vol. 178, p. 517–560, 751–776. Philadelphia, 1914.

Jefferson, Mark.: Aridity and Humidity Maps of the United States. Geog. Rev., vol. 1, p. 203–208. New York, 1916.

Kearney, Thomas H., & Shantz, H. L.: The Water Economy of Dry-land Crops. U. S. Dept. Agr., Yearbook, 1911, p. 351–362. 1912.

Kincer, Joseph B.: Computing the Cotton Crop from the Weather Records and Ginning Reports. Mo. Weather Rev., vol, 49, p. 295–299. 1921.

Kincer, Joseph B.: Seasonal Distribution of Precipitation and its Frequency and Intensity in the United States. Mo. Weather Rev., vol. 47, p. 624–631, 17 maps and graphs. 1919.

Kincer, Joseph B.: A Correlation of Weather Conditions and Production of Cotton in Texas. Mo. Weather Rev., vol. 43, p. 61–65, 9 figs. 1915.

Kincer, Joseph B.: Daytime and Nighttime Precipitation and their Economic Significance. Mo. Weather Rev., vol. 43, p. 599–606, 6 figs. 1916.

Le Conte, J. N.: Snowfall in the Sierra Nevada. Sierra Club Bul., vol. 6, p. 310–314, incl. table, 11 diagr. San Francisco, 1908.

Lee, Charles H.: Water Resources . . . of Owens Valley, California. U. S. Geol. Survey, Water-Supply Paper 294, 135 p., incl. 8 figs., 65 tables, 30 pls. 1912.

Lee, Charles H.: Precipitation and Altitude in the High Sierra. Mo. Weather Rev., vol. 38, p. 1092–1099. 1911.

McAdie, Alexander G.: The Rainfall of California. Univ. Cal. Publ., Geog., vol. 1, p. 127–240, incl. tables, 10 figs., pls. 21–28. Berkeley, 1914.

Mill, Hugh Robert: Map Studies of Rainfall. Quart. Journ. Roy. Meteorol. Soc., vol. 34, p. 65–86, incl. 10 figs., pl. 1. London, 1908.

Millard, F. H.: Relative Reliability of Long-time Rainfall Records. Engin. News, vol. 73, p. 1212, incl. 2 tables, 2 figs. New York, 1915.

Palmer, Andrew H.: The Region of Greatest Snowfall in the United States. Mo. Weather Rev., vol. 43, p. 217–221, incl. tables, 13 figs. 1915.

Polis, P.: Zur täglichen Periode des Niederschlags. Meterol. Ztschr., vol. 19, p. 145–161, incl. 10 tables, 8 figs. Wien, 1902.

Reed, William G.: The Cyclonic Distribution of Rainfall in the United States. Mo. Weather Rev., vol. 39, p. 1609–1615, incl. 11 figs. 1911.

Reed, W. G., & Kincer, J. B.: The Preparation of Precipitation Charts. Mo. Weather Rev., vol. 45, p. 233–235. 1917.

Shantz, H. L.: Natural Vegetation as an Indicator of the Capabilities of Land for Crop Production in the Great Plains Area. U. S. Dept. Agr. Bur. Plant Ind. Bul. 201, 100 p., incl. 14 tables, 23 figs., 6 pls. 1911.

Smith, J. Warren: Relation Between the Annual Precipitation and the Number of Head of Stock Grazed per Square Mile. Mo. Weather Rev., vol. 48, p. 311–317. 1920.

Smith, J. Warren: Civilization Does Not Increase the Rainfall. Mo. Weather Rev., vol. 47, p. 858–860. 1919.

Smith, J. Warren: The Effect of Weather upon the Yield of Corn. Mo. Weather Rev., vol. 42, p. 78–93, incl. 15 figs. 1914.

Smith, J. Warren: The Relation between the Precipitation of the Ohio River above, and the Stream-flow at Cincinnati. U. S. Weather Bur. Bul. 40, 40 p., incl. tables, diagr. 1912.

Stineman N. M.: Average Rainfall in the Light of the New Bedford Record. Engin. News, vol. 73, p. 1213, incl. table, 1 fig. New York, 1915.

Stockman, William B.: Periodic Variation of Rainfall in the Arid Region. U. S. Weather Bur. Bul. N, 15 p., 1 map. 1905.

Symons, C. J.: Effect of Wind on the Catch of Rainfall. Mo. Weather Rev., vol. 27, p. 454–455. 1899.

Talman, C. F.: The Causes of Droughts. Country Gentleman, vol. 77, no. 6, p. 25. Philadelphia, Feb. 10, 1912.

Thiessen, A. H.: The Value of Snow Surveys as Related to Irrigation Projects. U. S. Dept. Agr., Yearbook, 1911, p. 391–396, incl. fig. 13, pls. 37–42. 1912.

Tolley, Howard Ross: Frequency Curves of Climatic Phenomena. Mo. Weather Rev., vol 44, p. 634–642, incl. 3 tables, 4 figs. 1916.

U. S. Weather Bureau (Henry, Alfred J., & others): Weather Forecasting in the United States. 370 p., incl. maps, diagr., front. (map), 40 charts (part. fold). Washington, 1916.

Wallace, H. A.: Mathematical Inquiry into the Effect of Weather on Corn Yield in the Eight Corn Belt States. Mo. Weather Rev., vol. 48, p. 439–446. 1920.

Wallis, B. C.: Rainfall of the United States. (*5 papers under various titles.*) Mo. Weather Rev., vol. 43, p. 11–14, 5 figs.; p. 14–24, 23 figs.; p. 170–175, 19 figs.; p. 176–178, 1 fig.; p. 267–274, 1 chart. Washington, 1915.

Ward, R. DeC.: The Snowfall of the United States. Scientific Monthly, vol. 9, p. 397–415, map. Nov. 1919.

Ward R. DeC.: Some Characteristics of the Rainfall of the United States. Scientific Monthly, vol 9, p. 210–223. Sept., 1919.

Ward, R. DeC.: Mean Annual Rainfall of the United States, with Notes on the New Chart of Average Annual Precipitation. Mo. Weather Rev., vol 5, p. 338–345, 1 map. 1917.

Ward, R. DeC.: Rainfall Types of the United States. Geog. Review, vol. 4, p. 131–144, 15 figs. New York, August, 1917.

Ward, R. DeC.: The Thunderstorms of the United States as Climatic Phenomena. Second Pan American Scientific Cong., Proc., vol. 2. Washington, 1917.

Widtsoe, John A.: Dry Farming. xxii + 445 p., incl. 111 figs., 1 pl. New York, Macmillan, 1911.

BIBLIOGRAPHIES OF PRECIPITATION.

Fassig, Oliver L., & others: Bibliography of Meteorology. Part II, p. 237–242. U. S. Signal Service, 1891.

Herbertson, A. J.: The Distribution of Rainfall over the Land. 70 p., 14 pls., p. 60–63. London, John Murray, 1901.

Milham, Willis Isbister: Meteorology. xvi + 549 p., incl. tables, ills., diagr., 50 charts, p. 261–263, 523–526. New York, Macmillan, 1912.

U. S. Department of Agriculture: Meteorology in Experimental Station Record. Washington, monthly. (Current.)

U. S. Weather Bureau: Bibliography in Monthly Weather Review. Washington, monthly. (Current.)

SOURCES OF PRECIPITATION DATA.

Goodnough, X. H.: Rainfall in New England. Journ. New England Water Works Assoc., vol. 29, p. 237–438, incl. tables, diagr., pls. 22–24. Boston, 1915.

Henry, Alfred J.: Climatology of the United States. U. S. Weather Bur. Bul. Q. 1012 p., incl. tables, diagr., 33 pls. 1906.

McAdie, Alexander G.: The Climatology of California. U. S. Weather Bur. Bul. L. 290 p., incl. tables, diagr., 12 charts, 7 pls. 1903.

Schott, Charles A.: . . . Precipitation . . . in the United States . . . Smithsonian Contributions to Knowledge, no. 222, 175 p., incl. tables, 8 pls. Washington, 1872.

U. S. Weather Bureau: Summaries of Climatological Data of the United States by Sections (tables). Various dates. (Each section is revised and reprinted when the previous edition is exhausted.) Summaries for the whole United States were collected as U. S. Weather Bureau Bul. W. Washington, 1912.

U. S. Weather Bureau: Climatological Data for the United States by Sections (tables) 13 numbers a year (12 monthly and No. 13, annual summary) since 1914. "Printed at the several Section Centers, assembled and bound at the Washington Office for service use and exchange." (Current.)

U. S. Weather Bureau: Monthly Weather Review. Washington, monthly. (Current.)

U. S. Weather Bureau: Weather, Crops, and Markets. Washington, weekly. Prior to Jan. 1, 1922, published as "National Weather and Crop Bulletin." (Current.)

U. S. Weather Bureau: Snow and Ice Bulletin. Washington, weekly during the winter. (Current.)

INSTRUCTIONS FOR RECORDING PRECIPITATION.

Marvin, C. F.: The Measurement of Precipitation. U. S. Weather Bur., Circular E, Instrument Division, ed. 3, 37 p., figs. 1910.

U. S. Weather Bureau: Instructions for Cooperative Observers. Circulars B and C, Instrument Division, ed. 5, 37 p., 10 figs. 1915.

PRECIPITATION AND HUMIDITY.

Precipitation includes rain, melted snow, sleet and hail. The standard U. S. Weather Bureau rain gauge is installed at all stations whose records were used in preparing the precipitation maps in this section of the Atlas.

Source of Data.—Records for the uniform 20-year period 1895 to 1914 form the basis of all the principal charts and diagrams. During these 20 years weather observations have been extended into nearly all portions of the country, which permits more exact deductions regarding the comparative distribution of precipitation than have heretofore been possible. The stations having records for the full 20-year period number only about 1,600; hence additional shorter records have been used from about 2,000 other stations. These shorter records lie within the same period, 1895–1914, and vary in length from 10 to 19 years, except for some of the less developed sections of the far West, where, owing to the limited data available, a few records of under 10 years have been used.

A few of the long records have occasional short breaks, and these records have been completed by interpolating the missing values, considering for that purpose the records of near-by stations. The reduction of the short records to the uniform 20-year period has been accomplished by comparing their values with those made at near-by long-record stations during the periods the short-record stations were in operation and applying the ratios for the short periods to the 20-year averages of the long-record stations. As a rule, each short record was compared with two or more near-by records covering the full period, and the results averaged.

No such extensive compilation of precipitation data has previously been undertaken by the Weather Bureau nor has it been possible heretofore, on account of lack of observations, to show so accurately the local details and variations of this important climatic element in the more recently developed portions of the country and at the higher altitudes in the West.

Cooperative observers' records.—Of the 3,600 records used in the preparation of the charts, about 200 were made at the regular observing stations of the Weather Bureau, and the others by cooperative and special observers, mostly the former. Thus the accumulation of the large amount of data necessary for the preparation of these charts has been made possible only by the cooperation of public-spirited citizens in every section of the country, who have taken and recorded for many years daily observations of the amount of precipitation. Most of these records cover the full 20-year period without a break, and many were made during the entire time by the same observer. They were made under the supervision of, and have been carefully checked by, trained officials of the Climatological Service of the Weather Bureau, which insures that they represent actual conditions as nearly as these can be determined. After the shorter records were reduced to the full 20-year period, and all averages computed, the data were plotted on large topographic maps, upon which lines were then drawn indicating areas having approximately equal amounts of precipitation. These large maps were then finally reduced to the dimensions shown in the accompanying charts. The uniform agreement of the data as shown by the figures for adjacent stations indicates that the observations at the several classes of stations, mostly cooperative, were made with remarkable accuracy.

Geographic distribution of stations.—Precipitation data can be satisfactorily shown for an extended area, such as the United States, only by means of charts based on averages for a definite period of sufficient length to give dependable results, and for a sufficient number of points to represent every section of the country (see fig. A). East of the Rocky Mountains these conditions are more or less fully met by available data in practically all localities, except that in some portions of the Appalachian Mountains more observations are needed. From the Rocky Mountains westward, however, no actual precipitation measurements for many of the more elevated and less accessible localities are available. It is now possible, however, to determine the amount of precipitation in those regions with assurance of a much greater degree of accuracy than has been possible heretofore owing to the fact that a considerable number of snowfall stations have been maintained in the higher mountains by the Weather Bureau for several years. The records from these stations are now available and have been used in the preparation of the accompanying charts. These records have been found especially valuable in studying the variations of precipitation with altitude in different localities and under different topographic and geographic surroundings and as an aid in drawing isohyetal lines through similar regions where few or no gauge records are available.

Presentation of Data.—In a publication of this character the presentation of data must necessarily be largely in the form of charts and graphs showing average conditions, but at the same time it is recognized that the value of such charts is greatly enhanced by supplementary maps and diagrams showing the variations from the average which may be expected from time to time and other noteworthy features. Therefore a number of auxiliary maps and graphs have been included.

Construction of the charts.—Owing to the existence of many and diverse factors operating to control the occurrence of precipitation, and the large variations in amounts frequently resulting, even in limited geographic areas, the problem of depicting by graphic means the actual amount of precipitation for the entire United States is one of considerable difficulty. The drawing of the isohyetal lines from station to station necessarily involves interpolations. Over relatively smooth land surfaces and for areas well represented by records these interpolations are not difficult to accomplish, but for mountainous regions where few precipitation measurements have been made, as in portions of our Western States, the process becomes more complex. Opinions differ as to the best procedure in attempting to depict the amount of precipitation in the absence of actual measurements. It is self-evident that precipitation charts can not show complete details for such regions, but at the same time users of these charts require that they show the probable conditions as nearly as it is possible to determine them.

Owing to the recent development of farming operations under irrigation in many of the fertile but arid valleys of the West, the question as to the amount of precipitation occurring at the higher elevations has become of great importance, as the flow of streams and hence the water available for irrigation is largely dependent upon mountain snowfall. It is especially important, therefore, to show normal conditions existing in these higher altitudes as nearly as possible, and a chart which omits details necessary for this purpose does not meet present-day requirements. For example, in the preparation of precipitation charts it may be literally correct to mark areas "20 inches plus" where 40 inches occur, but such a practice would be misleading and would not serve the purposes for which such charts are intended.

In drawing isohyetal lines for these less accessible regions, actual measurements, of course, should be the basis, but where few such observations have been made it is better to supplement the available data by such other evidences as may be at hand. Among these may be mentioned the known increase in precipitation with elevation, the character of vegetation, and the stream flow, in so far as these have been determined.

The accompanying charts have been constructed in accordance with these principles, and it is believed they present as accurate a picture of the general precipitation conditions as can be made from the available data.

Relative utility of the several charts.—Existing charts of average precipitation for the United States have been prepared mostly for the entire year, although there are a few for the summer half-year only, April–September. The principal difficulties in the application of statistics of annual precipitation arise, first, because there is always the possibility that, owing to the long period covered, large deficiencies in portions of the year, especially disastrous droughts in the season of critical plant development, may be concealed by excess precipitation at other times of year; and, second, because the annual amount gives no information as to seasonal distribution, which agriculturally is of great importance. For example, the eastern portion of South Dakota receives on the average between 20 and 25 inches of precipitation annually. This amount may or may not be sufficient for the successful prosecution of agricultural enterprises by ordinary farming methods, depending wholly on its seasonal distribution and the locality. The amount is sufficient in South Dakota, owing to its concentration in the growing season and the comparatively low rate of evaporation, but with a uniform seasonal distribution and more rapid evaporation it would be inadequate.

The charts of monthly precipitation also are not entirely satisfactory for many purposes, owing to the relatively large fluctuations in the monthly amounts, while the averages are sometimes unduly magnified by the occurrence of a few very heavy rainfalls which have little agricultural value.

Seasonal charts are less subject to the limitations mentioned for monthly and annual charts and are, therefore, better representations of precipitation in its relation to agriculture. Consequently, five double-page charts are presented, namely, one for the warm season, April to September, inclusive, and one for each of the four seasons, winter, spring, summer, and fall (figs. 8, 20, 30, 40, and 50). As a basis for the study of the relation of precipitation to agriculture the importance of these charts can scarcely be overemphasized.

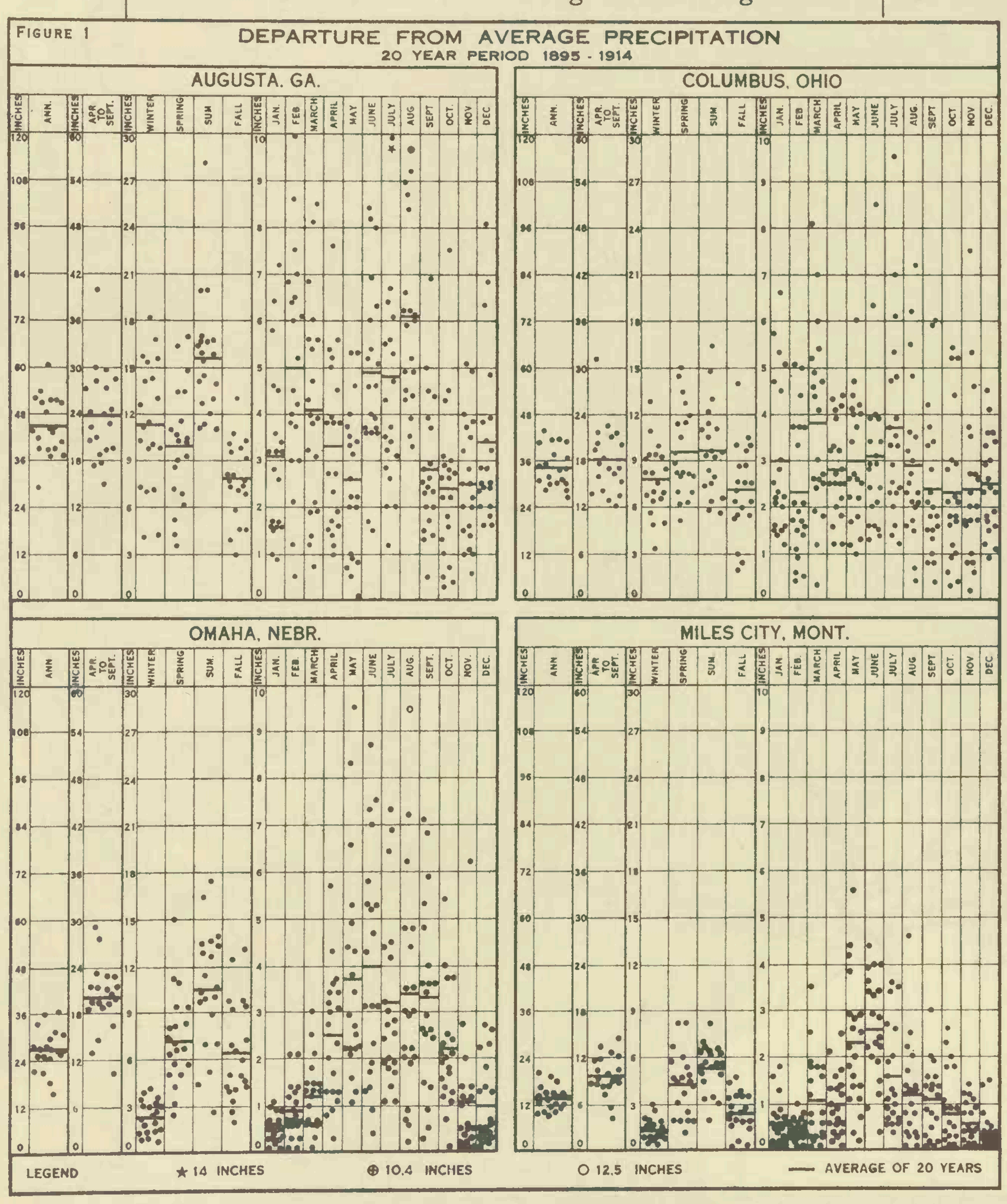


Figure 1.—Comparison of the dispersions of the annual, seasonal, and monthly precipitation about the average at selected stations for the 20 years, 1895–1914. The scales are drawn on a comparable basis—that is, the scale for the half year, comprising the warm season, is twice as large as the annual, each of the 4 seasons 4 times as large, and each of the 12 months 12 times as large. These graphs show the relative variations from the average that are likely to occur for the several periods covered by the various precipitation charts, and emphasize the tendencies to increasingly greater departures from the average with the decreasing length of the period covered. A dot represents the annual, seasonal, or monthly precipitation, as the case may be, for each year, and the heavy horizontal bars show the 20-year averages.

At the bottom of each of these charts is presented a graph which shows for a number of representative localities the seasonal precipitation for each of the 20 years on which the chart is based. On these graphs the amount for the season in each year is represented by a dot, the location of which shows the amount, and the mean of the values represented by the 20 dots for each station corresponds to the basis for the isohyetal lines of the large chart. These graphs show for different localities the variations in the seasonal amounts of precipitation likely to occur from year to year, and give an indication of the relative dependability of the means for different sections of the country.

Dependability of 20-year averages.—As the precipitation charts are based on averages covering the 20-year period 1895 to 1914, it is of importance to inquire as to their dependability; that is, would any other 20-year period likely show materially different results? A period of 20 years, admittedly, is not of sufficient length to give average values of precipitation that would not be changed by the addition of records for succeeding years, but a study of the available records has shown that the period is long enough to give average values sufficiently accurate for use in studying the distribution of precipitation as affecting agricultural enterprises. In this respect the future can be judged only from the past, and as an indication of the changes in the amounts of precipitation that may be expected from year to year during long periods of time, the annual amounts are shown in figure 6 for several stations having long records. The record for New Bedford covers 101 years, 1814 to 1914; that for Marietta 93 years; and the records for Oregon, Mo., Manhattan, Kans., Boise, Idaho, and Sacramento, Cal., are each 50 years in length. In these cases the averages for the 20-year period 1895 to 1914, as must be expected, differ somewhat from those of other periods of equal length, but it will be seen that the differences are not large enough to be of material agricultural significance.

Much has been written on the subject of secular variations in the amount of precipitation and so-called cyclical fluctuations, but the records in this country are too short to give any definite indications of these fluctuations. The longest records available cover a period of about 100 years, and a considerable number of stations have records ranging in lengths from 50 to 60 years. While a study of these records shows more or less definite and recognizable long-period fluctuations, they appear to be largely localized and no definite conclusions can be drawn for any area of considerable extent.

The long-period fluctuations are shown for the six stations comprising figure 6 by superposed curves, smoothed by the formula $\frac{a+4b+6c+4d+e}{16}=c'$, where c' is an adjusted average for the middle year of the series. This serves to reduce factors purely temporary and emphasizes tendencies extending over several years. So far as the available data indicate, the amount of rainfall in this country is neither permanently increasing nor decreasing in any locality.

Variations from average values.—The significance that attaches to an average made up of variables of different magnitudes depends on the nature of the dispersion of the variables about the average. If the individual

FIGURE 2

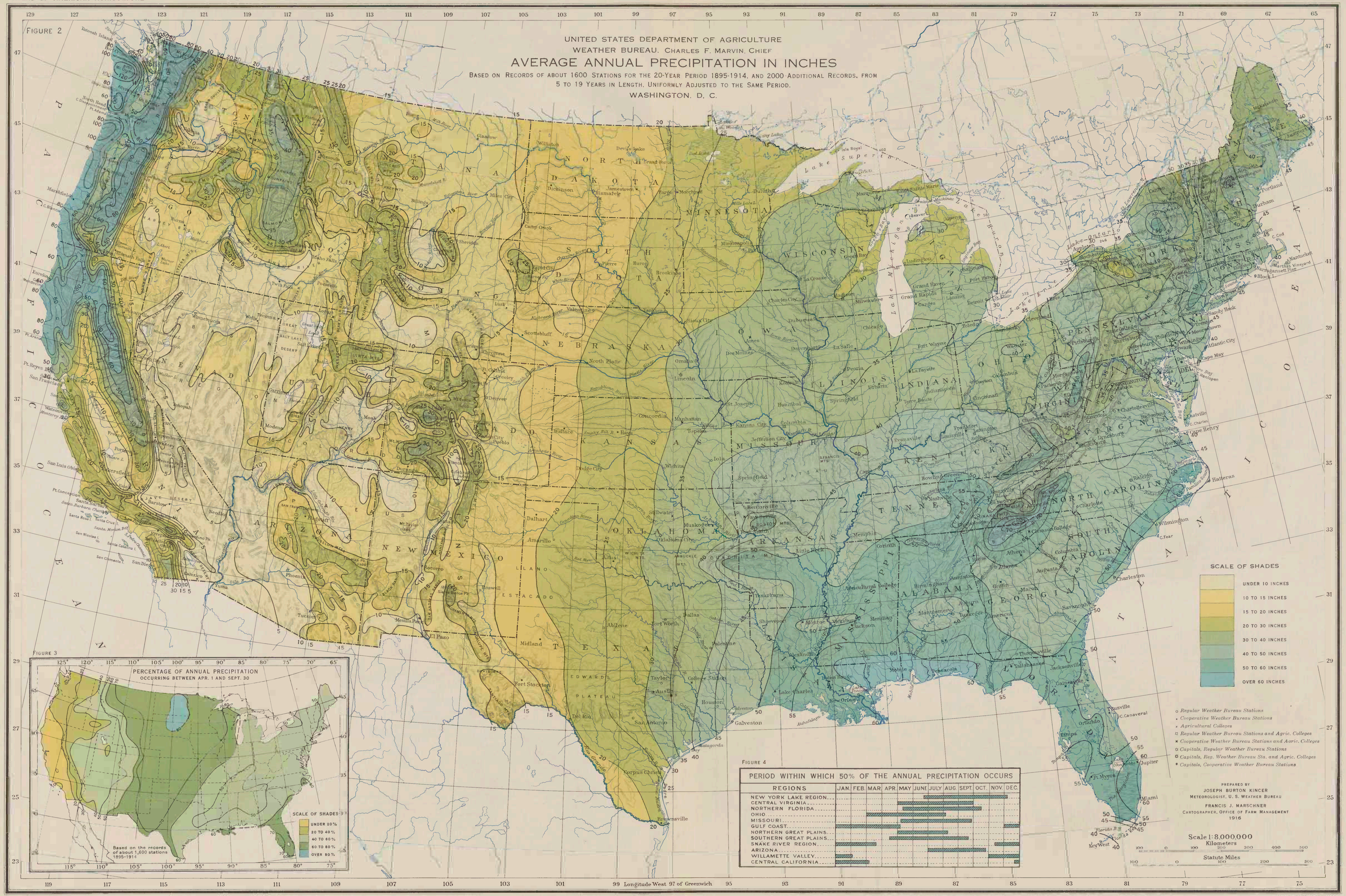


Figure 2.—This chart shows the average annual precipitation in different sections of the United States. East of the Rocky Mountains lines are drawn for each 5-inch interval, but in some of the mountainous districts of the West wider intervals had to be used. On the basis of precipitation, the United States may be divided into an eastern and a western part, the dividing line following approximately the 100th meridian, in the vicinity of which, from Canada to Mexico, the average annual precipitation is about 20 inches. In general, the eastern part has sufficient precipitation for successful farming by ordinary methods, but in the western part the amount of moisture over large areas is insufficient for the requirements of crop growth and here special methods of supplying moisture to or conserving it in the soil are often employed. Some of the principal features of the geographic distribution of precipitation in the United States may be briefly stated as follows: In the Pacific Coast States great differences in precipitation obtain, the average annual amounts ranging from more than 120 inches in portions of western Washington to less than 5 inches in the extreme southeastern portion of California. These localities represent the extremes of moisture conditions found in the United States. In the Interior Plateau region precipitation is scanty and generally insuffcent for ordinary farming operations. At the lower altitudes the average amounts range from less than 5 to about 10 inches, the larger amounts appearing mostly in the northern districts. Somewhat heavier precipitation occurs at the higher altitudes. At the lower altitudes of the Rocky Mountain States there are regions in which the average annual precipitation is less than 10 inches, but at the higher elevations it ranges from 20 to 40 inches, or more. East of the Rocky Mountains precipitation is comparatively uniform over large areas. The average annual amount ranges from about 15 inches along the eastern base of the Rocky Mountains to more than 80 inches in the southern Appalachian Mountains.

Figures 3 and 4.—The inset chart in the lower left hand corner shows the percentage of the annual precipitation which occurs during the six warmer months. In a portion of the Dakotas over 80 per cent occurs during these months, while in California less than 20 per cent is received during this period. The inset graph to the right shows the period of the year during which 50 per cent of the annual precipitation occurs.

FIGURE 5

ANNUAL PRECIPITATION AT SELECTED STATIONS FOR THE 20 YEAR PERIOD, 1895-1914 ARRANGED BY GEOGRAPHIC DISTRICTS

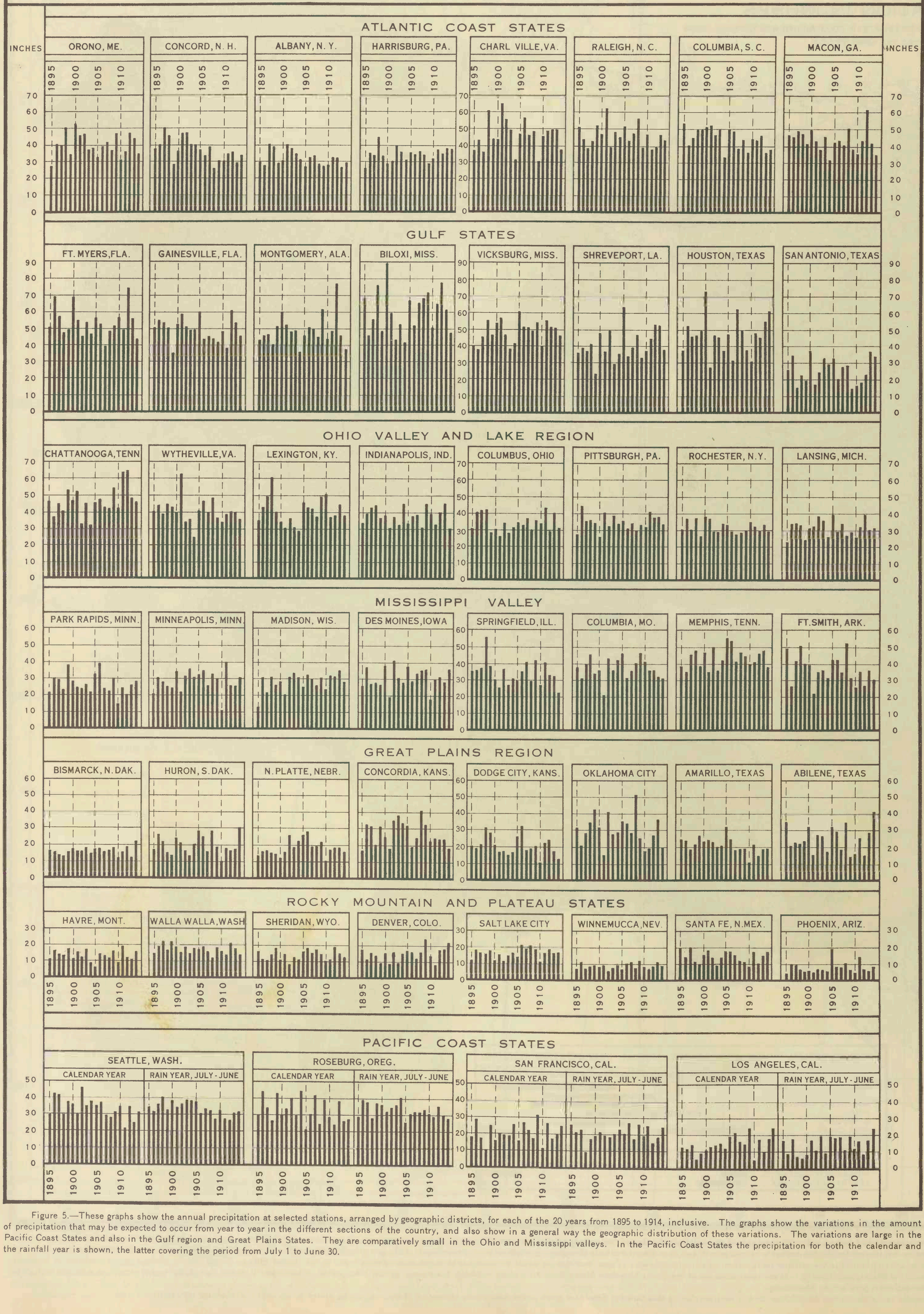


Figure 5.—These graphs show the annual precipitation at selected stations, arranged by geographic districts, for each of the 20 years from 1895 to 1914, inclusive. The graphs show the variations in the amount of precipitation that may be expected to occur from year to year in the different sections of the country, and also show in a general way the geographic distribution of these variations. The variations are large in the Pacific Coast States and also in the Gulf region and Great Plains States. They are comparatively small in the Ohio and Mississippi valleys. In the Pacific Coast States the precipitation for both the calendar and the rainfall year is shown, the latter covering the period from July 1 to June 30.

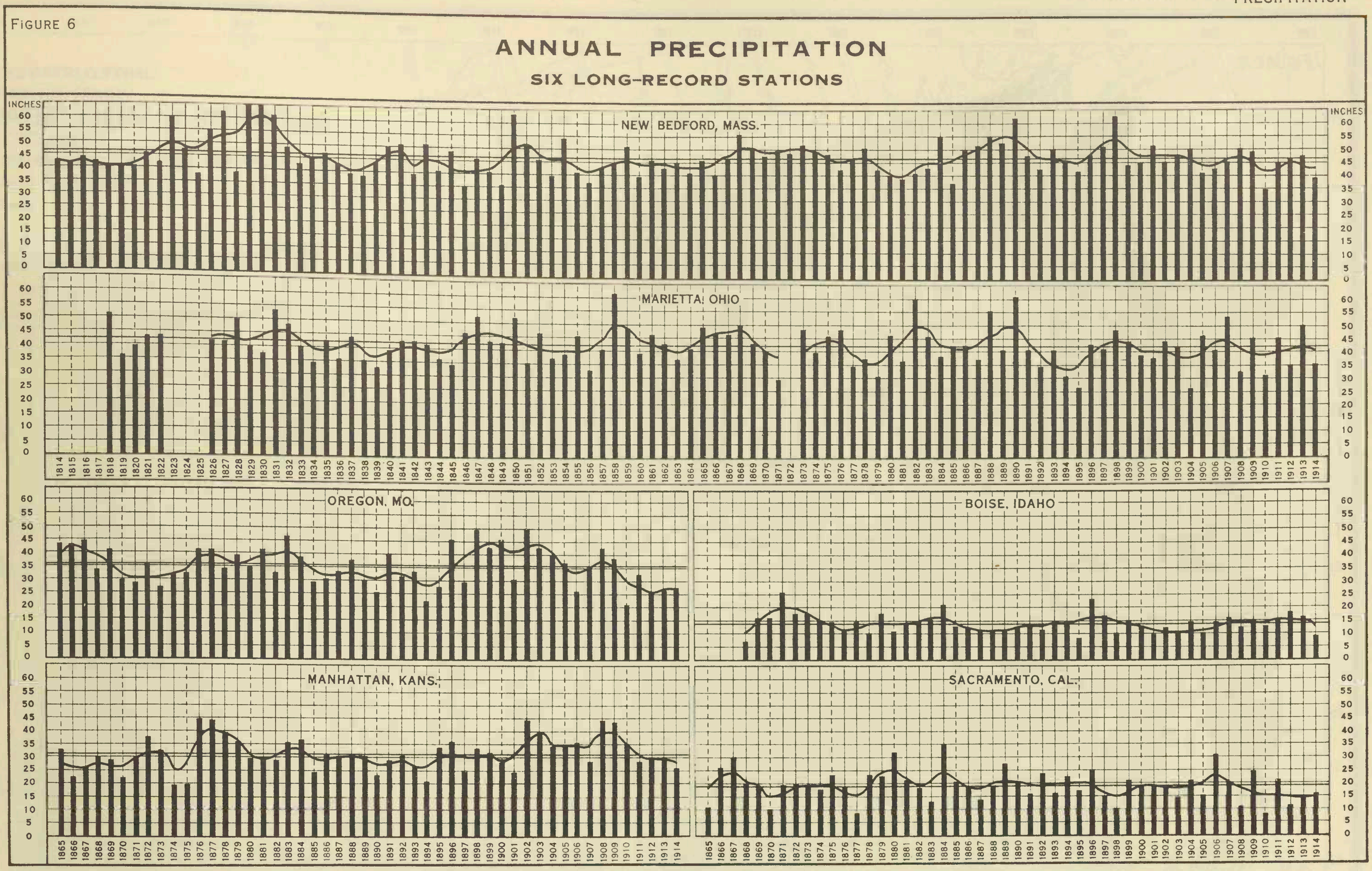


Figure 6.—Annual precipitation at six long-record stations—New Bedford, Mass.; Marietta, Ohio,; Oregon, Mo.; Manhattan, Kans.; Boise, Idaho; and Sacramento, Cal. While a study of the few long records available in this country show more or less definite and recognizable long-period fluctuations in precipitation, these appear to be localized and no definite conclusions can be drawn for any considerable area. The long period fluctuations are shown for these stations by superposed curves, smoothed by the formula $\frac{a+4b+6c+4d+e}{16}=c'$, where c' is the adjusted average for the middle year of the series. This serves to reduce the more or less accidental or temporary factors, and emphasizes tendencies extending over several years. So far as available data indicate, precipitation is neither permanently increasing nor decreasing in any portion of the United States.

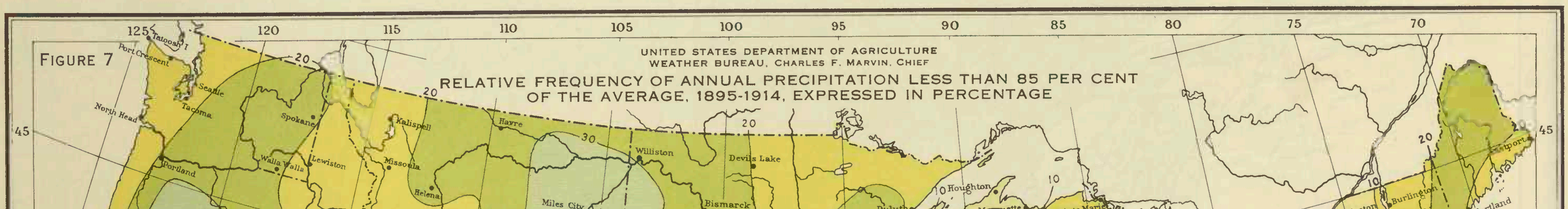


Figure 7.—This chart shows the relative frequency, expressed in percentage, during the 20-year period 1895-1914, that the annual precipitation was less than 85 per cent of the average. Periods of the year of four different lengths were used in the preparation of the several precipitation charts for this atlas, namely, annual, warm season (April-September), seasonal, and monthly. Of these, the percentage of the variations from the average is smaller for the annual than for any other period. The largest annual variations are found in the far Southwest, where at some places the annual precipitation was less than 85 per cent of the 20-year average in half the years or more. The areas of least variation are found in portions of the Lake region and Atlantic Coast States, and in central and eastern Tennessee, where amounts greater than 85 per cent of the average occurred in more than 90 per cent of the years.

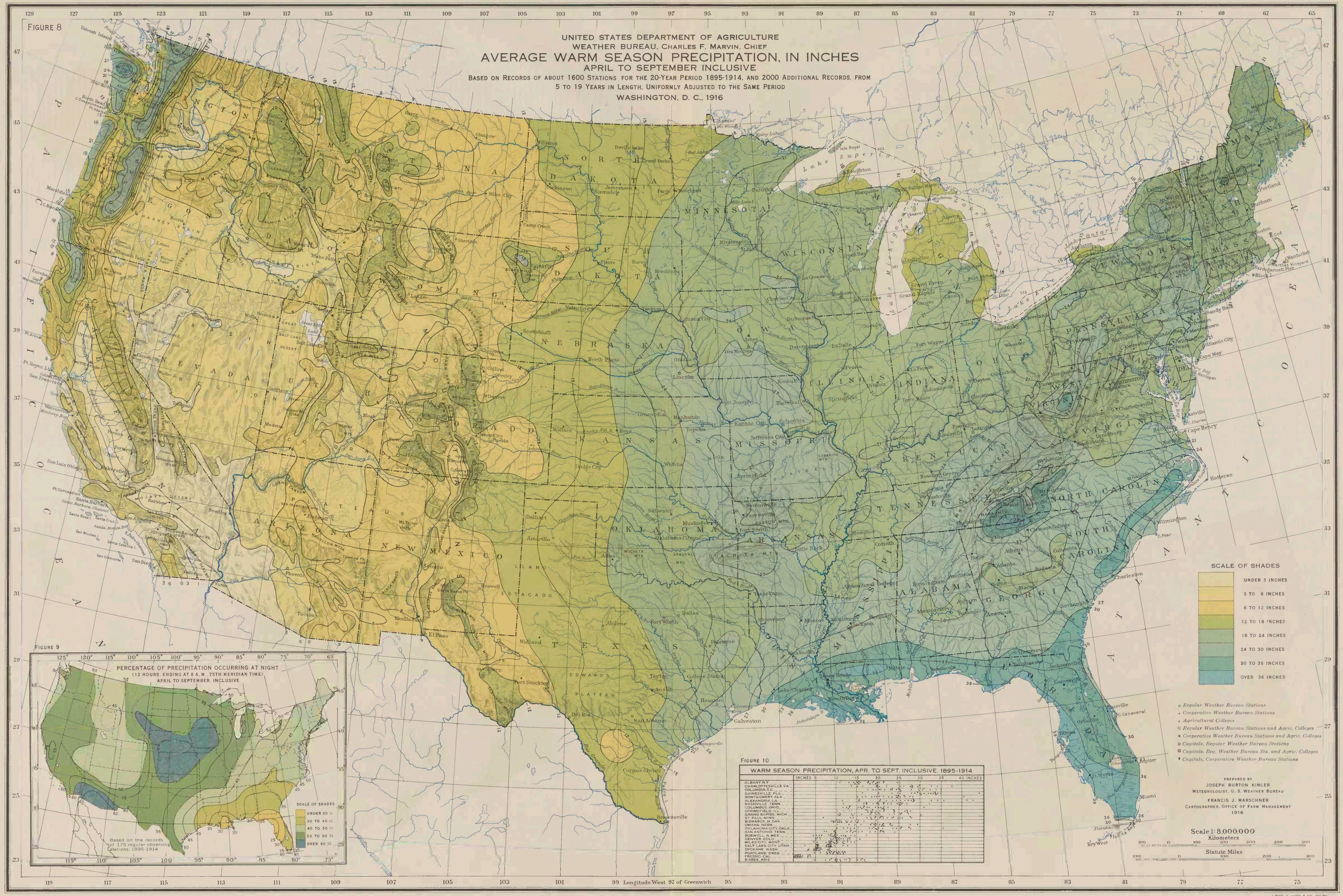


Figure 8.—This chart shows the average warm-season precipitation, April to September, inclusive. On the Pacific Coast this is the dry season, and precipitation is light as compared with the other six months of the year. In the Great Plains region, on the other hand, and extending eastward to include Wisconsin, northwestern Illinois, Iowa, northeastern Missouri, and most of Oklahoma, the greater part of the annual precipitation occurs during this period (see fig. 3). East of the Mississippi River and Lake Michigan the seasonal distribution of precipitation is more uniform, except in Florida and along the South Atlantic and Gulf Coasts, where there is a marked summer concentration.

Figures 9 and 10.—The inset chart in the lower left-hand corner shows the percentage of precipitation that occurred at night, 8 p. m. to 8 a. m., 75th meridian time, during the warm season, April to September, inclusive, for the 20-year period 1895-1914. In some of the interior districts from 50 to 65 per cent of the warm-season rainfall occurs at night, while in some southeastern localities less than 30 per cent of the total occurs during the night hours. The inset graph to the right shows for a number of representative stations, well distributed over the country, the total warm season precipitation that occurred in each of the 20 years whose record was used in preparing the large chart. It indicates the variations in warm season rainfall from year to year in different localities.

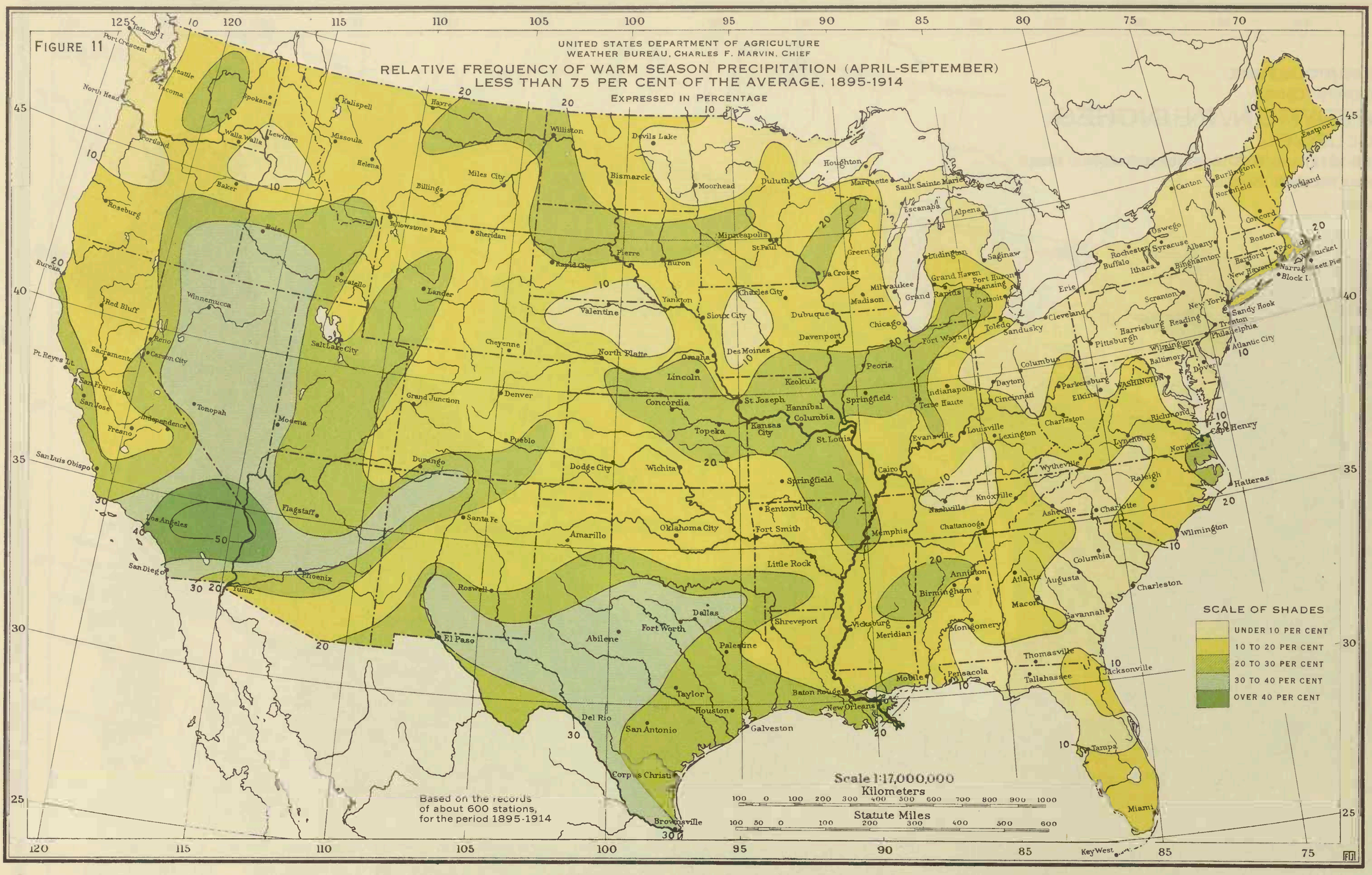


Figure 11.—The warm season precipitation is of great agricultural importance, especially in districts east of he Rocky Mountains, and the frequency of material variations from the average for this period is of especial significance. The above chart shows the relative frequency, expressed in percentage, during the 20-year period 1895–1914, that the total precipitation for the warm season, April–September, was less than 75 per cent of the average. The most frequent variations occur in southern California and portions of the adjoining States, where the warm-season rainfall was less than three-fourths of the average in from 8 to 11 years during the 20-year period. However, warm-season rainfall in these districts has little agricultural significance, as the amounts are usually too small for ordinary farming operations. Over the great agricultural districts east of the Rocky Mountains the warm-season precipitation fell below 75 per cent of the average amount in only 2 to 4 seasons during the 20 years.

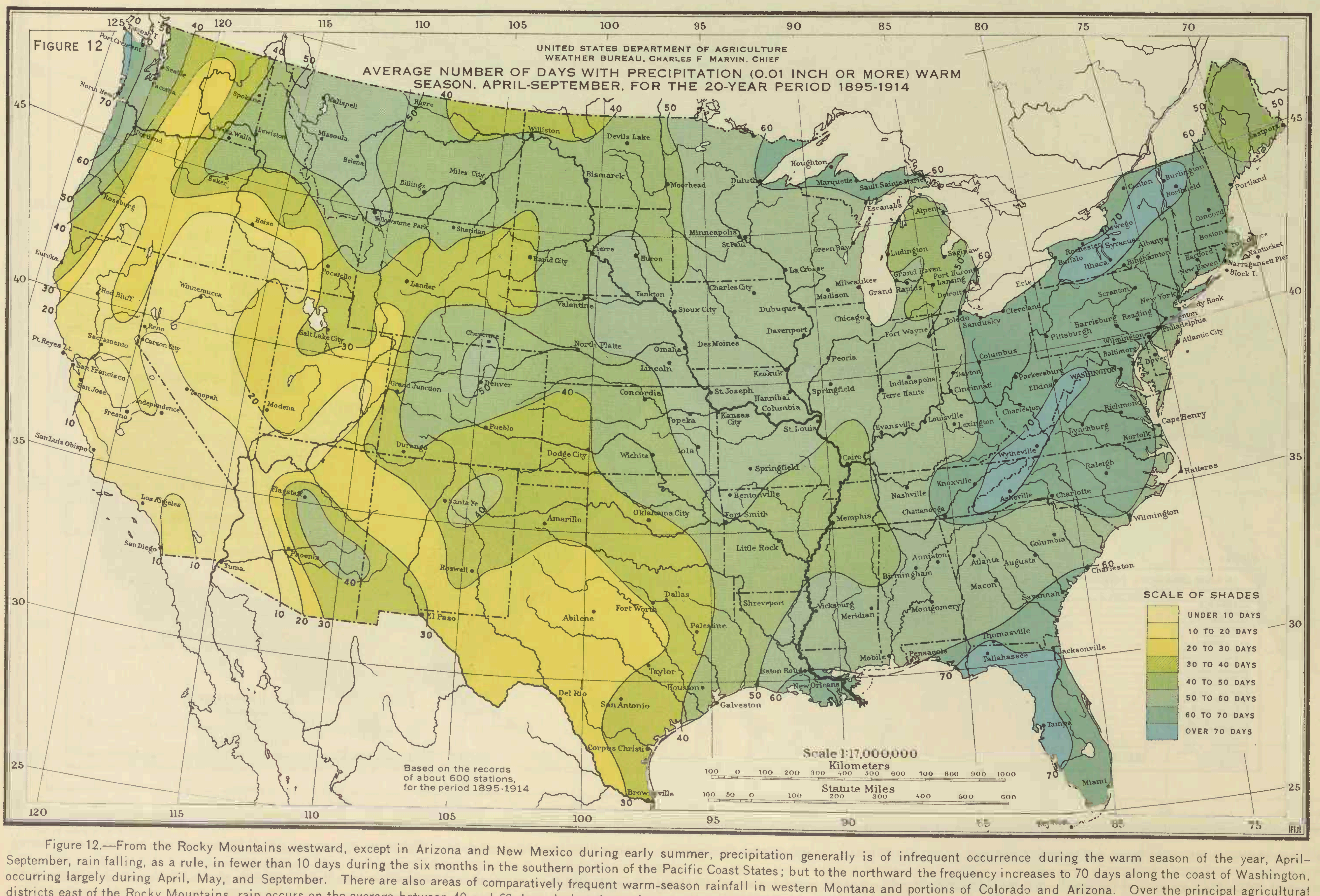


Figure 12.—From the Rocky Mountains westward, except in Arizona and New Mexico during early summer, precipitation generally is of infrequent occurrence during the warm season of the year, April–September, rain falling, as a rule, in fewer than 10 days during the six months in the southern portion of the Pacific Coast States; but to the northward the frequency increases to 70 days along the coast of Washington, occurring largely during April, May, and September. There are also areas of comparatively frequent warm-season rainfall in western Montana and portions of Colorado and Arizona. Over the principal agricultural districts east of the Rocky Mountains, rain occurs on the average between 40 and 60 days during these six warmest months. The areas of most frequent occurrence are in portions of Florida and in the Appalachian Mountain districts, where rain falls on the average on more than 70 days during the period.

FIGURE 13

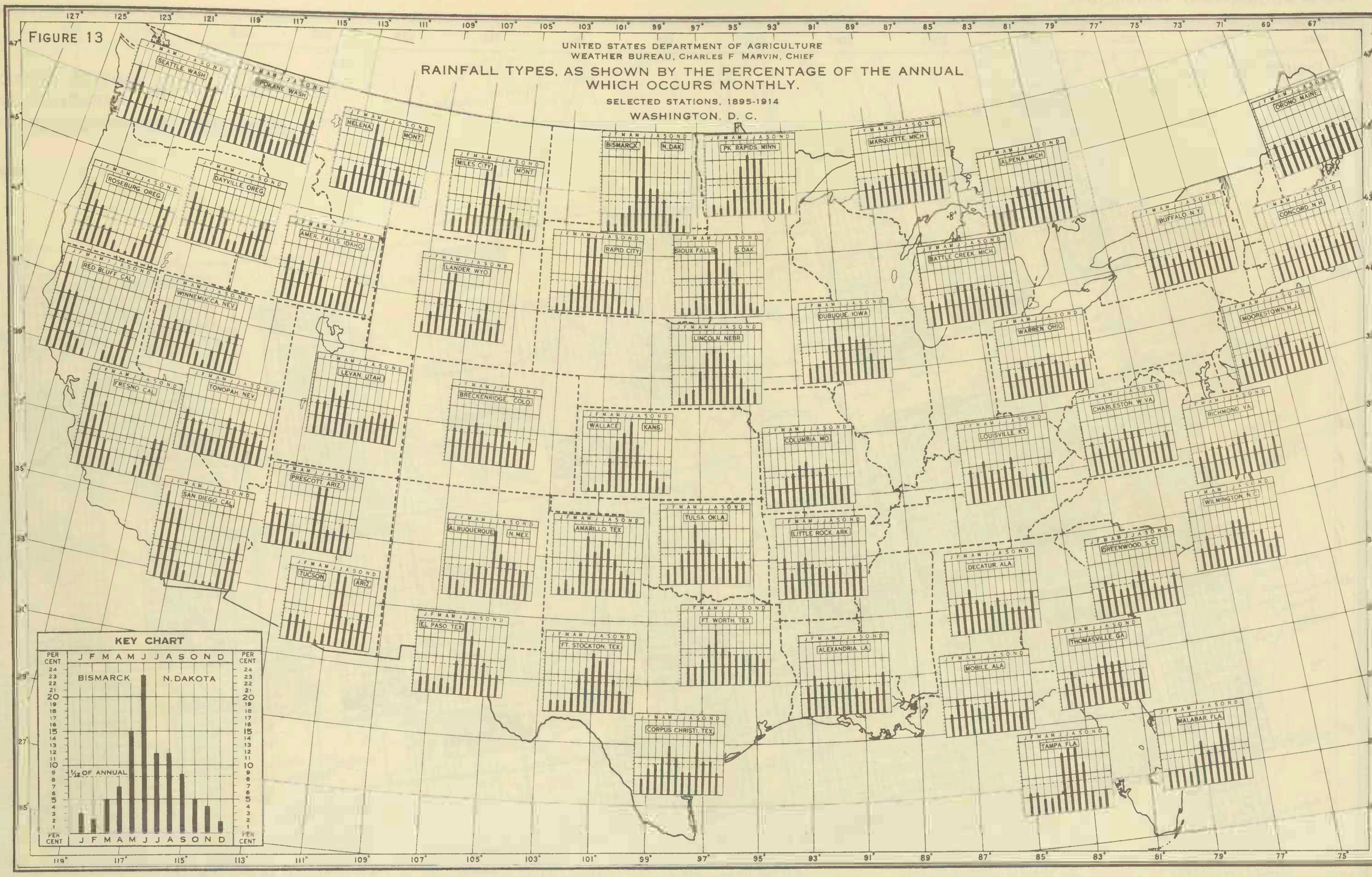


Figure 13.—This chart shows the percentage of the annual precipitation which occurs in each month. Among the several rainfall types that have been recognized in the United States the most noteworthy are the Eastern, Plains, Arizona, Sub-Pacific, and Pacific. Broadly speaking, the Eastern type may be considered as including the originally forested Eastern portion of the United States, except the Florida Peninsula, and is characterized by a comparatively uniform distribution of precipitation throughout the year. The Plains type includes the prairie and plains regions and extends westward to the crest of the Rockies. It is characterized by a marked concentration of rainfall in the late spring and summer months and by dry winters. The Arizona type, which is found in western Texas, New Mexico, and Arizona, is characterized by comparatively heavy rainfall during the months of July and August. In the Sub-Pacific type, which includes most of the country between the Rocky Mountains and the Sierra Nevada and Cascade ranges to the north of the Arizona type, the precipitation occurs mostly during the winter and spring months; while in the Pacific type, which extends westward from the Sierra Nevada and Cascade Mountains to the Pacific Ocean, the winters are wet and the summers are very dry.

values differ but little from the average, the latter is more representative than when wider variations appear.

In the consideration of precipitation charts based on average values for a definite number of years, the variations from year to year should always be taken into account. The nature and magnitude of these variations are, of course, not the same for different sections of the country, nor for different periods of the year. Of the three classes of charts, annual, seasonal, and monthly, the annual has the smallest relative variations, and the monthly the largest, with the seasonal holding an intermediate position. In figure 1 these dispersions about the average are shown in their relation to one another for four representative stations, Augusta, Ga., Columbus, Ohio, Omaha, Nebr., and Miles City, Mont.

The variations of precipitation from year to year are so erratic that no general rule is applicable, except that amounts less than the average usually occur in slightly more than half the years. Therefore, in studying charts showing the average amounts of precipitation, the fact that the amounts shown are usually available for plant development in fewer than half the years should not be lost sight of. Regions having more pronounced variations from year to year, have also proportionately more years in which less than the average amount occurs. This condition is brought about by the fact that in a series of years of sufficient length to give dependable averages there is usually found one or more years with exceptionally heavy rainfall, which may be considered as merely accidental, but which never-the-less raise the average value above the median. In the case of monthly precipitation it is not unusual for a positive departure to be greater than the average itself, but a negative departure of such magnitude obviously can not occur.

The graphs shown in figure 5 indicate for about 50 stations, well distributed throughout the country, the annual precipitation for each of the 20 years, 1895–1914, and also show the variations that occurred from year to year. The graphs in figure 15 show the monthly distribution of precipitation for a large number of representative stations.

The occurrence of minus departures from the average precipitation is usually of greater agricultural significance than plus departures, as most growing plants suffer more frequently from a lack of moisture than from a superabundance. Consequently a number of charts have been prepared showing for the year, the summer half-year, and for each month from March to October, inclusive, the relative number of times in the 20-year period 1895–1914 that the precipitation was less than certain significant percentages of the average. Figure 7 shows the relative number of times the annual amount was less than 85 per cent of the average; figure 11 shows the relative number of times during the warm season that the precipitation was less than 75 per cent of the average; and figures 58 to 65 show for each month from March to October the relative number of times the monthly amount was less than 50 per cent of the average. These charts are based on about 600 records for the uniform 20-year period 1895–1914.

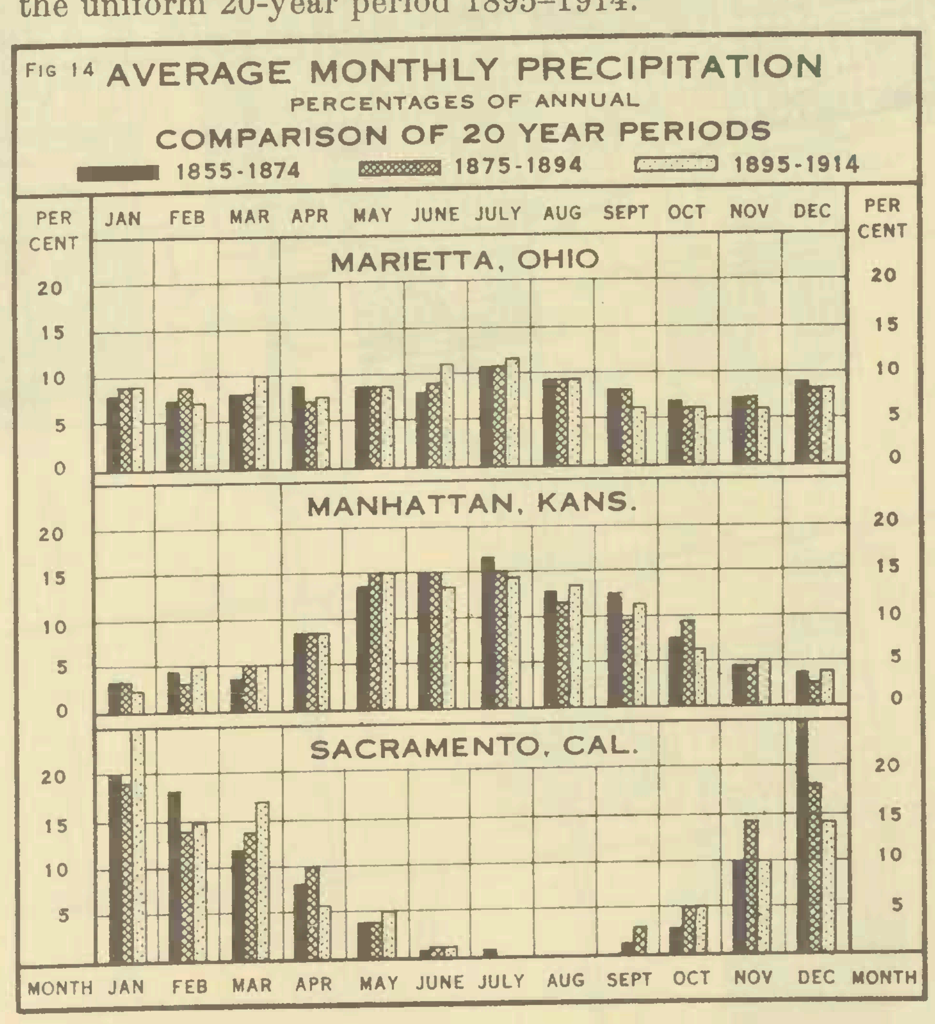


Figure 14.—Average percentages of the annual precipitation that occurred in each month during three successive 20-year periods at Marietta, Ohio, Manhattan, Kans., and Sacramento, Cal., representing the three principal rainfall types in the United States. Solid bars represent the period 1855–1874; closely shaded center bars, 1875–1894; and lightly shaded bars at the right, 1895–1914.

Factors Affecting Precipitation.—Among the many factors which control the geographic distribution of precipitation, the most effective are: Distance from the main sources of moisture supply, oceans, seas, etc., and prevailing surface drift of the air; topographic features, especially differences in elevation and mountain barriers; and location with reference to the most frequent paths of cyclonic storms. In some instances these may operate singly, but in most cases the distribution of precipitation is the result of a combination of several factors.

Influence of large bodies of water.—Whether or not the amount of precipitation decreases with increasing distance from large bodies of water, and whether nearness to the water results in abundant precipitation, depends mostly on the direction of the wind and the temperature conditions. In the United States precipitation is usually heavier near the source of moisture supply, the oceanic influence being clearly indicated by the diminution in precipitation over the successive mountain ranges and valleys with progress inland from the North Pacific Coast. There are, however, some important exceptions; for example, the coast of southern California, where rainfall is scanty, and also the western Gulf Coast, where precipitation as a rule is not greater than over the interior districts to the northward. This geographic distribution has also seasonal variations. During the winter months, for example, the contrast between the average amount of precipitation in the northern interior districts east of the Rocky Mountains, far removed from the source of moisture supply, and that occurring in the central Gulf States, near the supply, is marked, the former, receiving usually less than 1 inch a month and the latter about 4 inches. For the spring and summer months, however, the distribution is more nearly uniform; in fact, in portions of the plains States and in the lower Missouri and middle Mississippi valleys the rainfall for the late spring and early summer is greater than in any other agricultural section of the country.

Topographic influence.—In the case of topographic influence, few important exceptions can be cited to the general rule that in mountainous regions precipitation increases with elevation, although this increase is by no means uniform in different localities, nor does it always continue to the highest elevations. Mountain masses exert a marked influence on precipitation, not only over the mountains themselves, but often over large areas to the leeward. From the Rocky Mountains westward the distribution of precipitation is largely determined by topographic conditions. The surface of this region is characterized by successions of mountain chains, either in massive ranges or more or less detached, with intervening narrow valleys, usually trending north and south. This condition of land relief results in large variations in the amounts of precipitation, even in near-by localities. The most notable example of this influence is found in the Sierra Nevada and Cascade ranges, which present a nearly unbroken massive ridge through California, Oregon, and Washington, lying almost at right angles to the path of the prevailing moisture-laden winds that blow from the ocean with no interruption except by the low Coast Range.

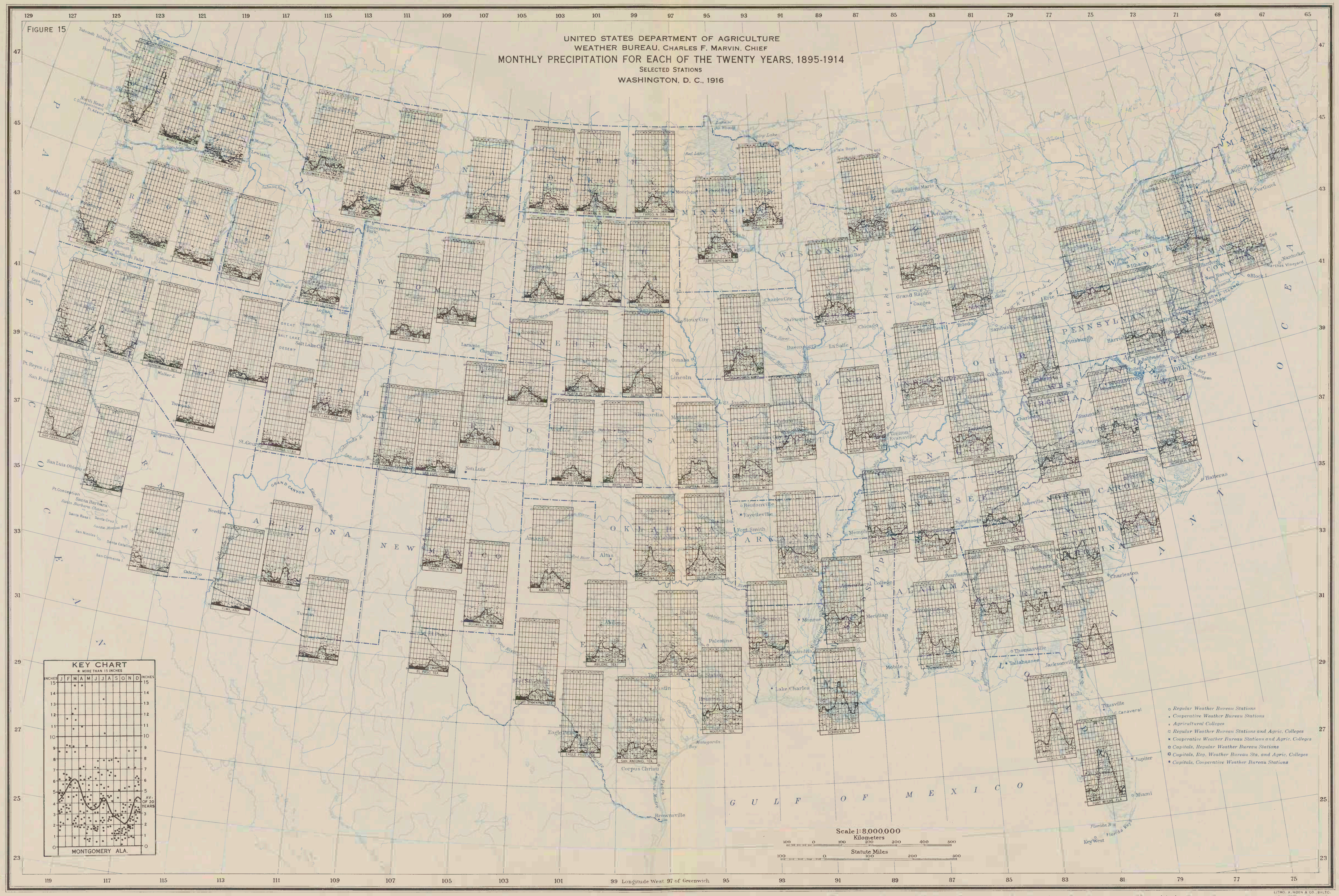


Figure 15.—These graphs show for selected stations the precipitation for each of the 12 months for each of the 20 years from 1895 to 1914, inclusive. The amount of precipitation for each month is shown by a dot, and the average monthly amounts are shown by the heavy lines. The graphs show the seasonal distribution of precipitation and also the variations from the average monthly precipitation that may be expected to occur in different sections of the country. These variations are large along the Pacific Coast. East of the Rocky Mountains they are largest, as a rule, in regions having the greatest average amounts of precipitation. From the Great Lakes region eastward the variations are comparatively small.

While investigations made for these mountains indicate that the zone of maximum precipitation probably lies at altitudes ranging from 4,000 to 6,000 feet, the increase in precipitation with altitude is far from uniform in more irregular mountain masses, especially those farther removed from ocean influences and with intervening mountain barriers. Therefore, it is not safe to assume that the relations found to exist in the Sierra Nevada hold good for the Rocky Mountain system. In fact, the meager information at hand indicates that the zones of maximum annual precipitation are usually found at considerably higher levels in the Rockies than in the Sierra Nevada. In portions of the Appalachians this topographic influence is likewise markedly shown. At several stations in the southern portion of these mountains, and also on Mount Washington, N. H., a precipitation of more than 80 inches occurs annually on the average, or nearly twice as much as at near-by lower elevations.

The influence on precipitation of successive mountain ranges and valleys disposed at right angles to the prevailing wind direction is markedly shown by conditions in the States of Washington and Idaho. Here on the windward side of the Olympic range in Washington the average annual precipitation is more than 100 inches. Immediately behind this belt of heavy rainfall lies the Puget Sound Basin, where the annual averages range generally from 20 to 50 inches. Next in succession come the more massive Cascades, with annual averages reaching more than 80 inches on the windward side, and these in turn are followed by the Columbia Plateau, where less than 10 inches are recorded at the lower elevations. To the east the precipitation increases with increasing elevation, until in the mountains of northern Idaho more than 40 inches are usually received.

Cyclonic influence.—In general, regions situated near the more frequented cyclonic paths receive greater amounts of precipitation than those more remote, but for the United States, at least, there are some important exceptions to this rule. The effect of such situation on the amount of precipitation is seen to some extent in the northern Rocky Mountain region, as compared with the localities to the southward, where cyclonic storms are less frequent and precipitation lighter, and, in combination with other favorable conditions, this factor accounts for the heavy rainfall on the North Pacific Coast. East of the Rocky Mountains, however, modifying influences are such that the areas of heaviest precipitation are considerably removed from the most frequented paths of cyclonic storms. Cyclonic storms frequently cross the northern Plains and Lake States, but the average annual amount of precipitation in these northern localities, 25 to 35 inches, is less than in the regions lying to the south, precipitation increasing in amount from the northern tier of States to the Gulf of Mexico, where the rainfall is about 60 inches. Likewise, the Northeastern States come under the direct influence of these storms more frequently than any other section of the country, yet precipitation here is only moderate in amount, notwithstanding the fact that the disturbances produce moist onshore winds.

Convectional currents.—Local convectional circulation of the atmosphere due to surface heating, also plays an important part in the production of precipitation, especially during the summer season, when much of the rainfall is the result of thunderstorms. These disturbances, known as heat thunderstorms, occur with greater frequency in the Gulf States than in any other portion of the country, which fact accounts in part for the comparatively heavy rainfall in that region.

PRECIPITATION TYPES.—As a result of the foregoing and other factors, not only the annual amount but also the seasonal distribution of precipitation varies greatly in different parts of the United States. Henry has recognized 11 more or less distinct types of seasonal distribution of precipitation, namely, Pacific, Sub-Pacific, Arizona, Mountain, Eastern Foothills, Plains, Gulf, Southern Appalachian and Tennessee, South Atlantic, Middle Atlantic and New England, and Lake Region and Ohio Valley. With respect to their agricultural significance and areas covered, several of these types may be combined, in this brief discussion, so there will remain six principal groups, broadly designated Pacific, Sub-Pacific, Arizona, Plains, Eastern, and Florida types. The Eastern type includes the originally forested eastern section of the United States, excepting the Florida Peninsula where the seasonal distribution of rainfall is so distinct as to become a separate type; the Plains type includes the prairie and plains regions and extends westward to the crest of the Rocky Mountains; the Arizona type includes western Texas, New Mexico, and Arizona; the Sub-Pacific type occupies the central and northern portions of the Plateau region between the Rocky Mountains and the Sierra Nevada and Cascade ranges; and the Pacific type extends from these ranges westward to the Pacific Ocean.

In this connection it is of interest to inquire whether the relative monthly distributions of precipitation, as indicated by the percentage graphs (fig. 13), are permanent, or whether at least some of the less distinctive types shown for the 20-year period in question might be materially altered by the adoption of a different series of years. Figure 14 shows for Marietta, Ohio, Manhattan, Kans., and Sacramento, Cal., representative stations of the Eastern, Plains, and Pacific types of precipitation, respectively, the variations for three consecutive 20-year periods, 1855 to 1874, 1875 to 1894, and 1895 to 1914. The variations for each month as shown for these types are about in proportion to the respective fluctuations occurring from year to year in the individual monthly amounts. That is, the Eastern and Plains types are more constant in relative monthly distribution than is the Pacific type, but in each case the distinguishing characteristics are maintained in each of the three periods. However, these graphs indicate that caution should be exercised in pointing out the less distinctive types from data based on a period as short as 20 years. For example, in the case of Marietta, the first period, 1855 to 1874, indicates that the rainfall for May is greater than for June, but the two later periods do not show this; while at Manhattan, the first period indicates the occurrence of more rain in June than in May, but this is not the case in the other two periods. In the case of Sacramento, the irregularity in the percentages for individual months shows that the amounts of precipitation received in that locality are extremely irregular, with great variations from year to year in the monthly totals.

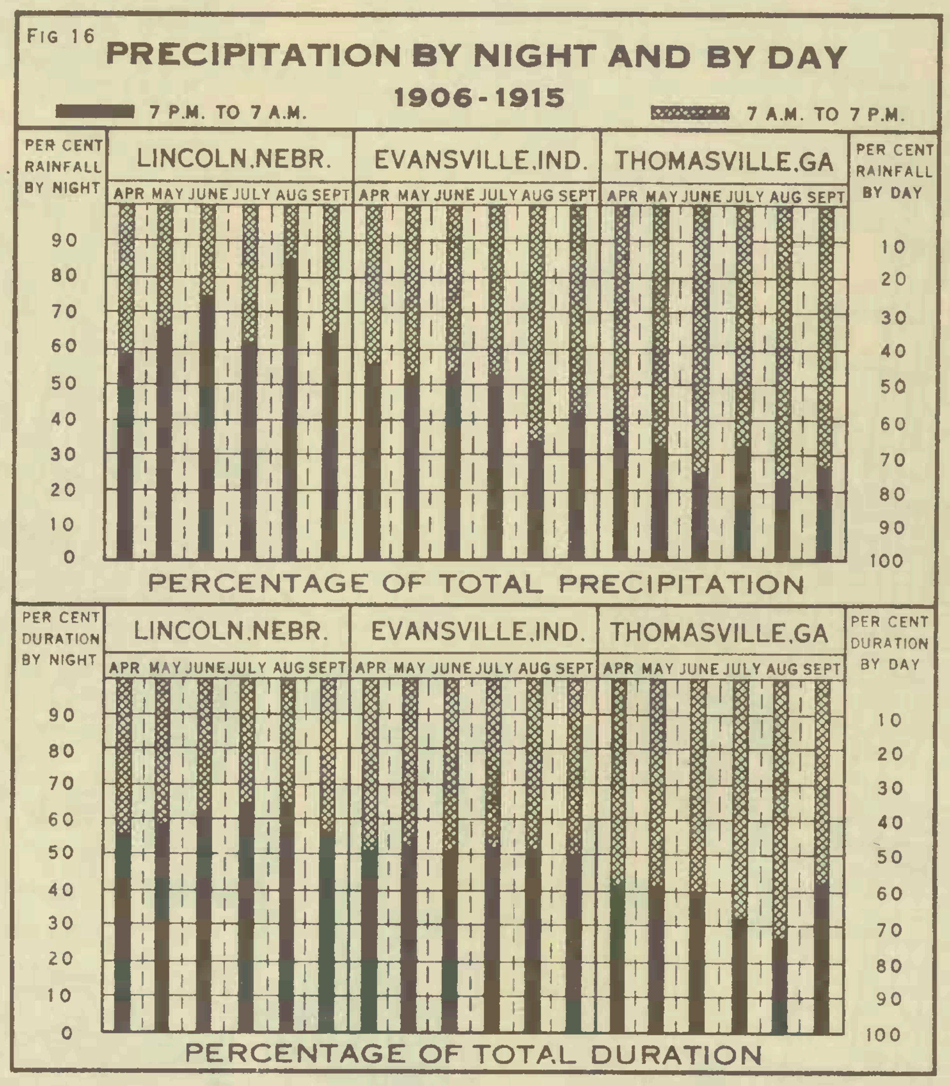


Figure 16.—Percentage of the total rainfall and duration of rain occurring at night (7 p. m. to 7 a. m. local standard time) and during the day (7 a. m. to 7 p. m.), for the months and at the stations indicated, for the 10-year period 1906–1915. Heavily shaded portions indicate nocturnal percentages. In the western portion of the Corn Belt about two-thirds of the precipitation during the warm season occurs at night, and in the east central portion of the Belt about one-half occurs during these hours. In the eastern portion of the Cotton Belt, on the other hand, only a little more than one-third of the warm season rainfall occurs during the night.

Pacific type.—This type is found in the Pacific Coast States from the Sierra Nevada and Cascade ranges westward to the Pacific Ocean. Its characteristic features are a marked winter concentration of precipitation and a summer dryness. In the western portions of Washington and Oregon from 40 to 50 per cent of the annual precipitation occurs during the winter months, December to February, the percentages increasing from north to south, amounting in California to 50 or 60 per cent (see fig. 13).

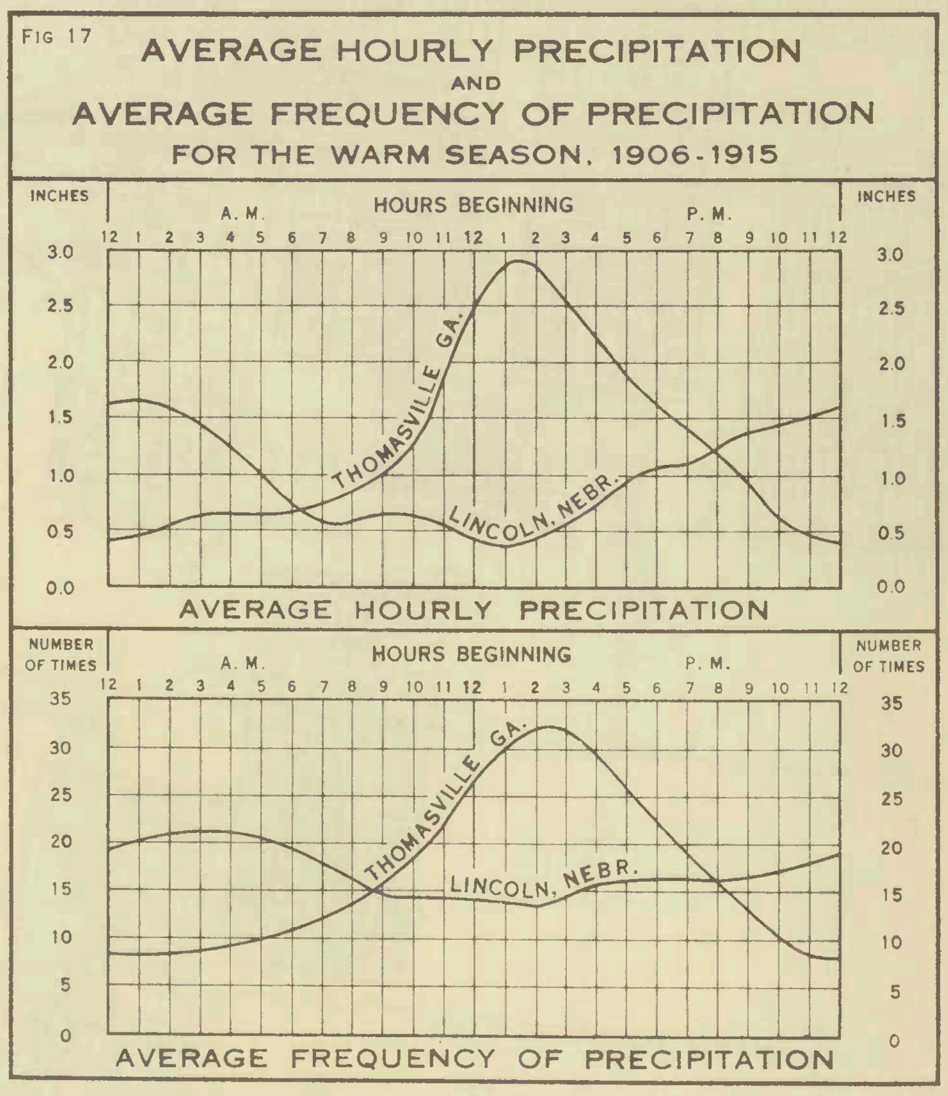


Figure 17.—The average hourly amount and frequency of precipitation for the warm season, April–September, for the 10-year period 1906–1915, at Lincoln, Nebr., and Thomasville, Ga. The nocturnal rainfall is comparatively heavy in the Corn Belt, the maximum occurring soon after midnight, whereas the heaviest rains in the Cotton Belt occur during the daytime, most frequently in the early afternoon. The values shown are the average hourly amounts received during the entire 6-months period.

The total precipitation for the winter (see fig. 20) on the windward sides of the Sierra Nevada and Cascade Mountains, as well as in the more or less detached members of the Coast Range north of the fortieth parallel, is, on the average, between 30 and 40 inches or more, while on the western side of the Olympic Mountains near the coast in Washington there is an area with more than 50 inches. The amounts occurring in the valleys increase from south to north. In the southern portion of the Great Valley of California the average amounts are less than 4 inches for the three winter months, but they increase to between 14 and 20 inches at the northern end of the valley. In the Willamette Valley and Puget Sound region the winter precipitation averages between 15 and 20 inches.

For the spring months, March to May (see fig. 30), the Pacific type of precipitation averages about one-half as much as for the winter, except that in the Cascade Mountains it is about two-thirds as great. In California the summer (see fig. 40) is practically rainless, except for an occasional shower in the mountains, and the rainfall is light to the northward, except that comparatively heavy rains occasionally continue into June (fig. 38). The proportion of the annual amount received during the summer months ranges from about 1 per cent in most of California to about 10 per cent in the vicinity of Puget Sound.

The rainy season sets in over the northern portion of the Pacific coast earlier than over the southern, the rainfall by November (fig. 53) becoming heavy in portions of Oregon and Washington, this being, in fact, the month of maximum rainfall in those localities. The precipitation for the fall months (see fig. 50) in the Pacific coast region ranges from 30 per cent of the annual amount in the northern portion to about 15 per cent in the southern.

Sub-Pacific type.—The designation "Sub-Pacific" has been given to the type of precipitation occurring in the eastern portions of Washington and Oregon and in Idaho, Nevada, and Utah. The seasonal distribution of precipitation over this region is distinguished from the Pacific type by the absence of a marked winter concentration, the precipitation for the spring months, except in the higher northern mountains of this region, being about the same as that occurring during the winter months. In the Columbia River Valley it is somewhat less, but in much of Nevada and Utah more rain falls during the spring months than in any other season. In the Sub-Pacific, as in the Pacific type, the rainfall during the summer months is very light and over considerable areas negligible. For the fall months it is about the same as for spring in eastern Washington and Oregon and in Utah, but somewhat less to the southward. Generally speaking, the Sub-Pacific type may be considered as one of fairly uniform distribution of precipitation for all months except the summer season.

The Sub-Pacific is a transitional type between the Pacific type and that found in the northern Rocky Mountains and Eastern Foothills, which culminates farther east in the Plains type. The relation between these rainfall types can best be seen from the inset charts of percentages of annual precipitation in each season, figures 21, 31, 41, and 51. On the chart of winter precipitation the area showing the highest percentages of the annual appears along the Pacific coast; on the spring chart this area appears in the northern Rocky Mountain and Eastern Foothill regions, but high percentages extend westward to Idaho and Nevada and eastward well into the Plains; while in summer the area has shifted still farther east and occupies the Plains proper. Thus as the season advances the area of relatively heavy precipitation occupies successive localities from the Pacific coast to the Great Plains.

The influences which control the occurrence of precipitation in the Sub-Pacific region are much the same as those which prevail west of the Sierra Nevada and Cascade ranges. The actual amount, however, is scanty during all seasons of the year, except at the higher elevations in the more northern States, and agricultural operations depend largely on irrigation or dry-farming methods.

Arizona type.—This type of rainfall prevails in extreme western Texas, New Mexico, Arizona, and in portions of southern Utah and Nevada, although it is not so well marked in these latter localities. It is characterized by relatively heavy rainfall during the months of July and August, when about 35 per cent of the annual precipitation occurs. April, May, and June are generally the months of least rainfall, and during the other months the distribution is quite uniform.

Summer rains in these districts are largely thundershowers occurring during the warmer portion of the day, caused mostly by convective circulation of the atmosphere. The amount and distribution of the winter rains depend largely on the frequency and position in latitude of cyclonic disturbances entering the United States from the Pacific.

Plains type.—This is a very important type agriculturally, covering as it does much of the great interior wheat and corn belts. It may be considered as including all the States from the Rocky Mountains eastward to the Great Lakes and the middle Mississippi River regions and thence southward to Missouri and Oklahoma. It is characterized by generous rains in the late spring and summer months and very light late fall and winter precipitation. It differs from the Arizona type in that the heavier rains begin earlier and end later, thus covering a longer period of the year, and also that precipitation occurs more frequently at night than in the afternoon (see fig. 9).

In portions of Montana and over small areas in the Dakotas and eastern Colorado the total precipitation for the three winter months averages less than 1 inch, while over the remaining area between the Rocky Mountains and a line extending from the Panhandle of

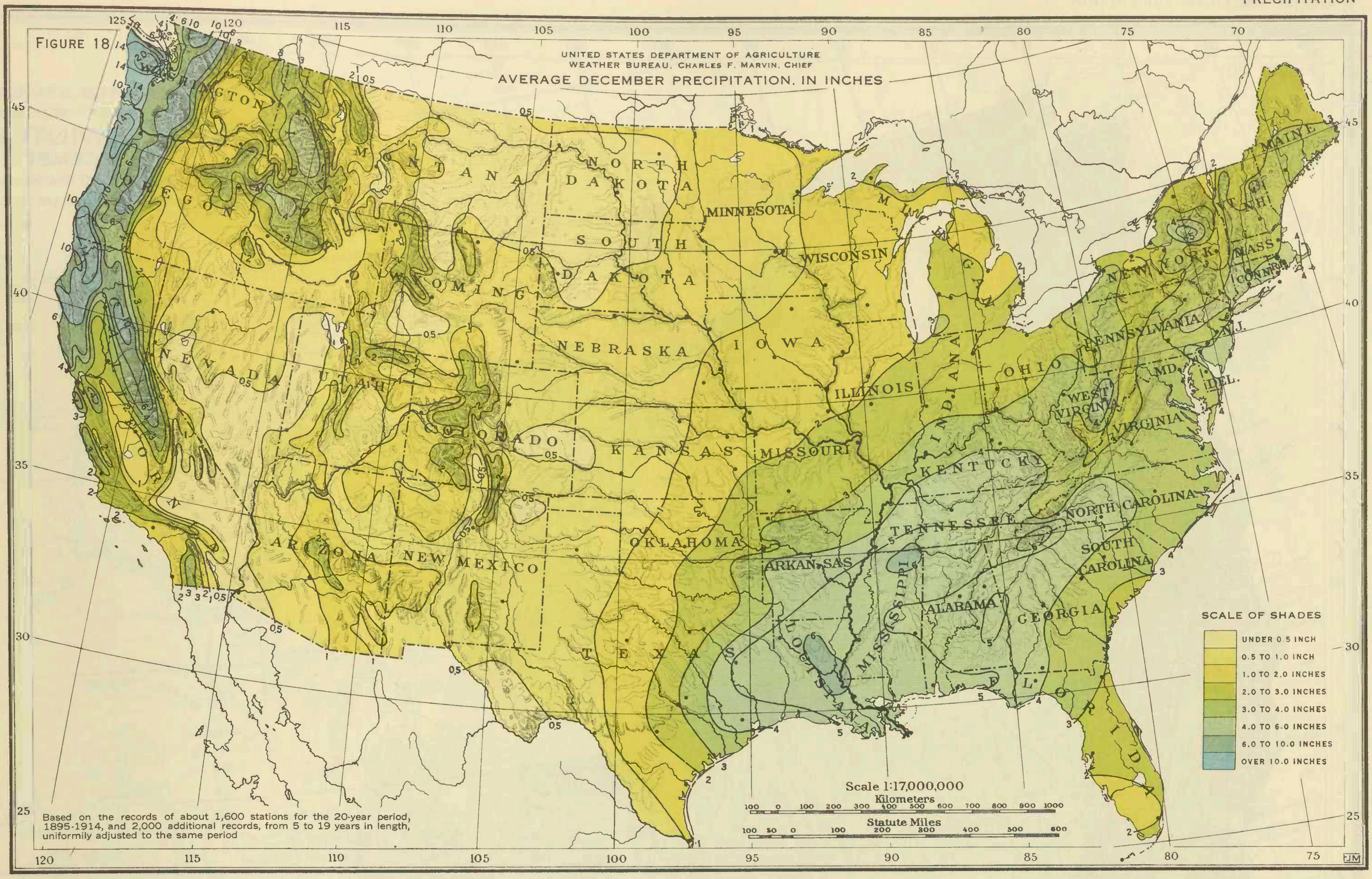


Figure 18.—By December in the Pacific Coast States the rainy season is usually well established, the central and northern portions of this region receiving more December precipitation than any other section of the country, and heavy snows have set in over the more elevated mountain districts. On the windward side of the Sierra Nevada, Cascade, and Coast ranges the monthly averages range from 10 to 14 inches or more of precipitation, and snow frequently accumulates to great depths. At the lower altitudes of the Interior Plateau and Rocky Mountain regions, and also over the Great Plains region, but little precipitation occurs during the month of December, large areas receiving usually less than 0.5 inch; but in the more elevated middle and northern Rocky Mountain districts from 2 to 4 inches or more occur on the average, almost wholly in the form of snow. In the eastern originally forested region the average December precipitation increases from about 2 inches along the northern border to 5 and 6 inches in the lower Mississippi Valley, but over the extreme Southeast there is a sharp diminution to less than 2 inches in portions of the Florida Peninsula.

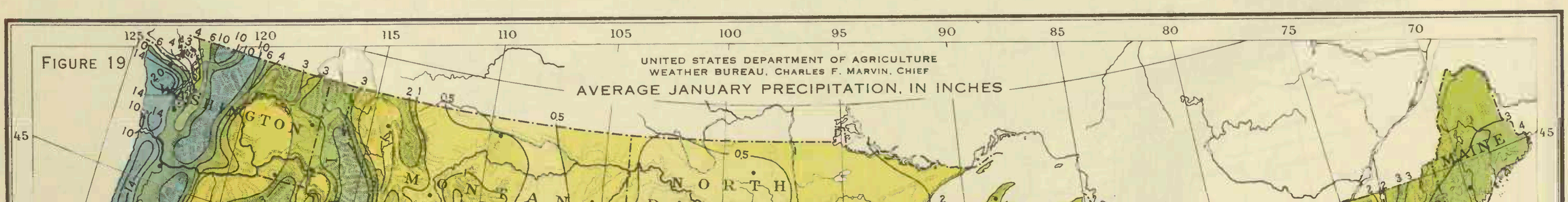


Figure 19.—In January the heaviest monthly precipitation in the United States occurs, as a rule, in the Pacific Coast region on the windward sides of the Coast Range, Sierra Nevada, and Cascade Mountains, where the monthly averages range from 10 to about 20 inches. To the eastward of the Sierra Nevada and Cascade ranges the precipitation is light, large areas receiving less than 1 inch. At the higher altitudes of the central and northern portions of the Rockies 4 inches or more occur, practically all in the form of snow. Large portions of the Plains region receive, on the average, less than 0.5 inch during the month, but to the southeastward there is a progressive increase to about 5 inches in portions of the lower Mississippi Valley and in the southern Appalachian Mountains. East of the Appalachians the amounts are smaller, considerable areas receiving, on the average, less than 3 inches.

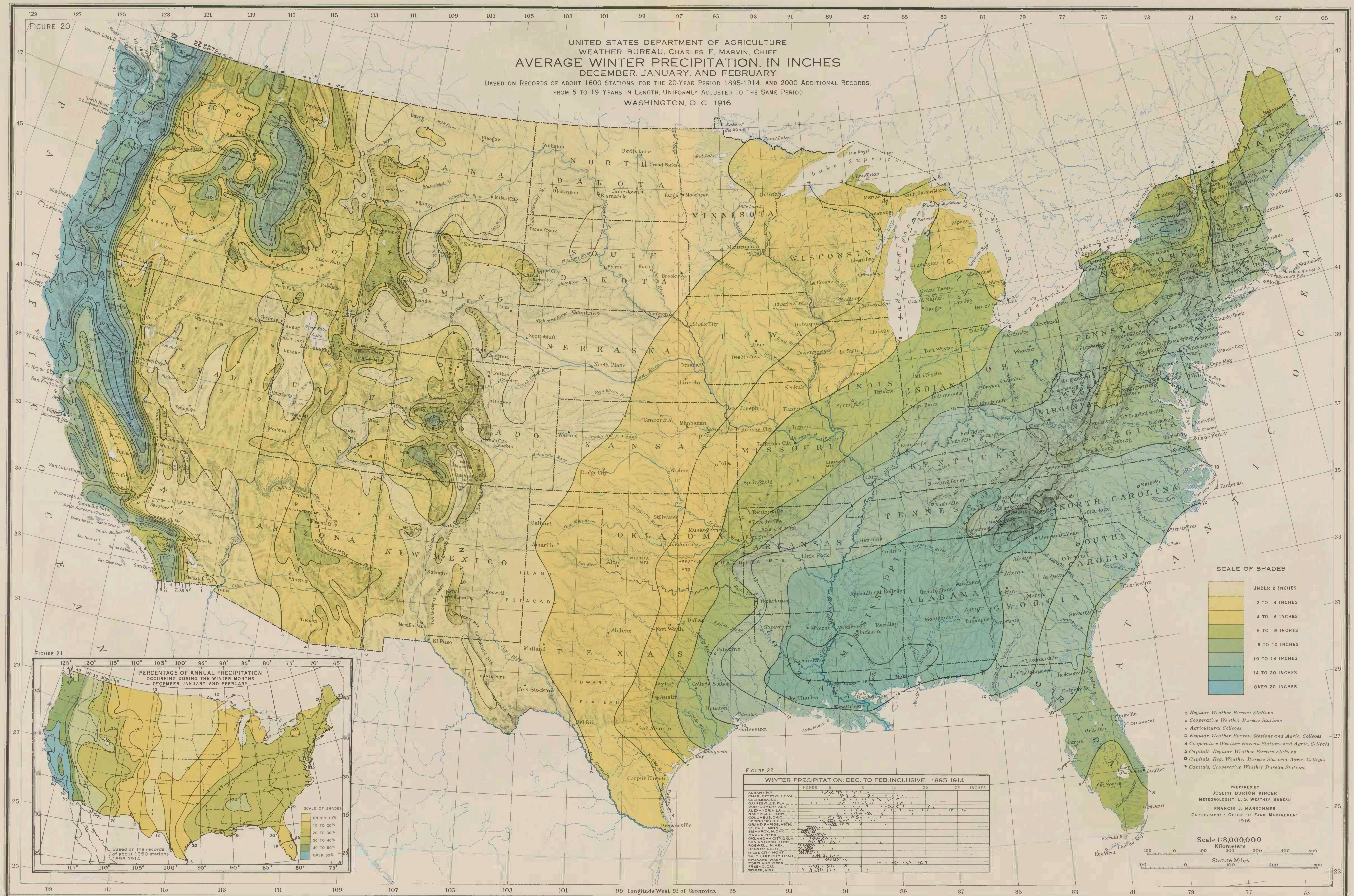


Figure 20.—This chart shows the average winter precipitation, December to February, inclusive. On the Pacific Coast winter is the wet season, precipitation from San Francisco northward being heavier than in any other portion of the United States. Maxima of 40 inches or more winter precipitation occur locally in the Sierra Nevada Mountains and along the Oregon and Washington coast. In the higher altitudes of the Rockies from 8 to 16 inches of precipitation occur during the winter season, wholly in the form of snow. In the Great Plains region the winter season is very dry, less than 2 inches occurring, as a rule, over most of the area. East of the Great Plains the winter precipitation gradually increases to a maximum of about 16 inches in southern Mississippi, in the higher altitudes of the southern Appalachians, and in the Adirondacks.

Figures 21 and 22.—The seasonal distribution of the annual precipitation varies widely in different sections of the United States. The inset chart in the lower left-hand corner shows the percentage of the annual precipitation that occurs during the winter months. In much of the Great Plains region the winter precipitation is small, generally less than 10 per cent of the annual, but in California the average winter precipitation is about half the average annual amount. The graph at the bottom to the right shows for a number of representative stations, well distributed over the country, the total winter precipitation that occurred in each of the 20 years whose record was used in preparing the large chart. It indicates the characteristics of distribution and variations from year to year in different localities.

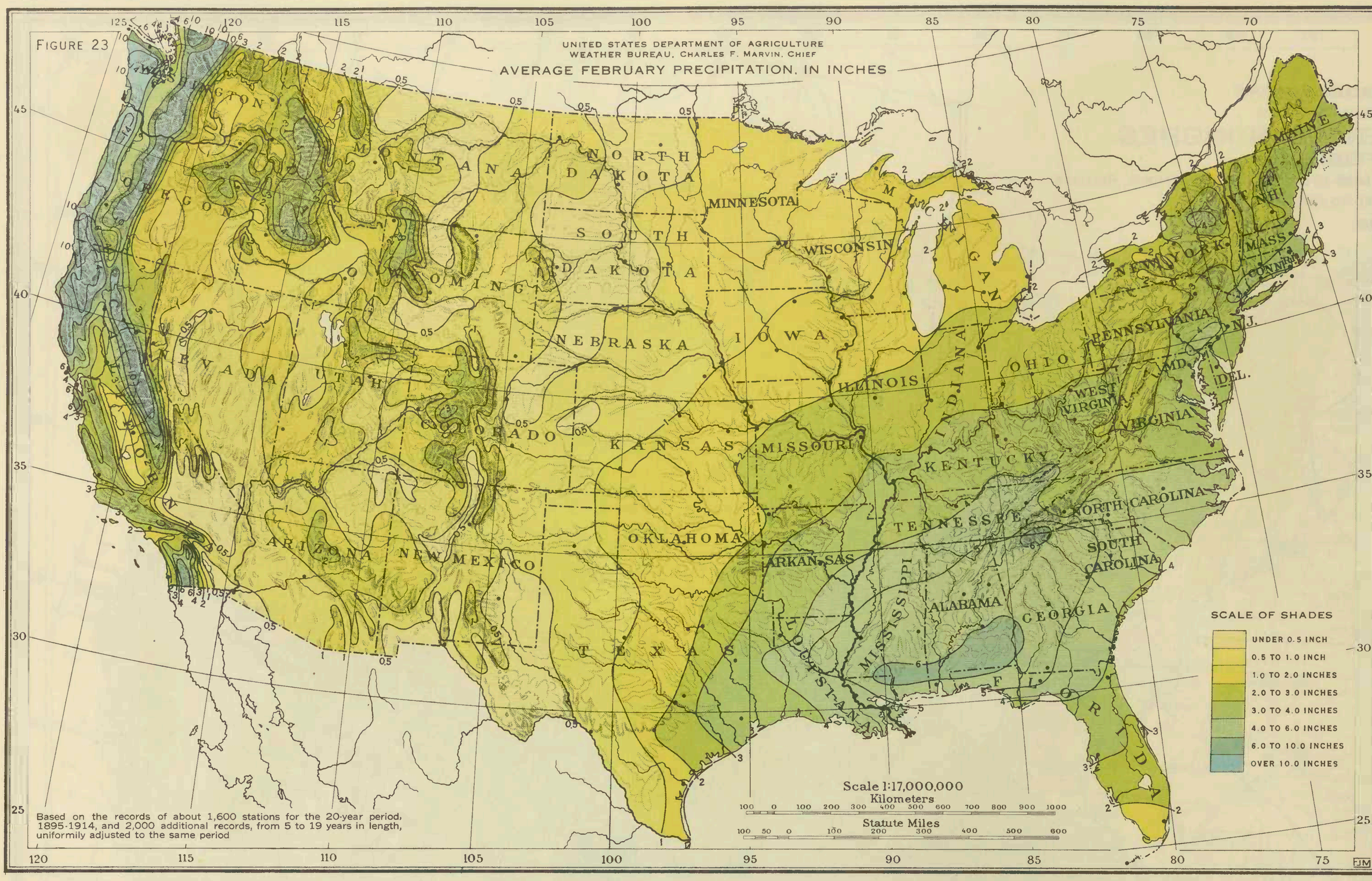
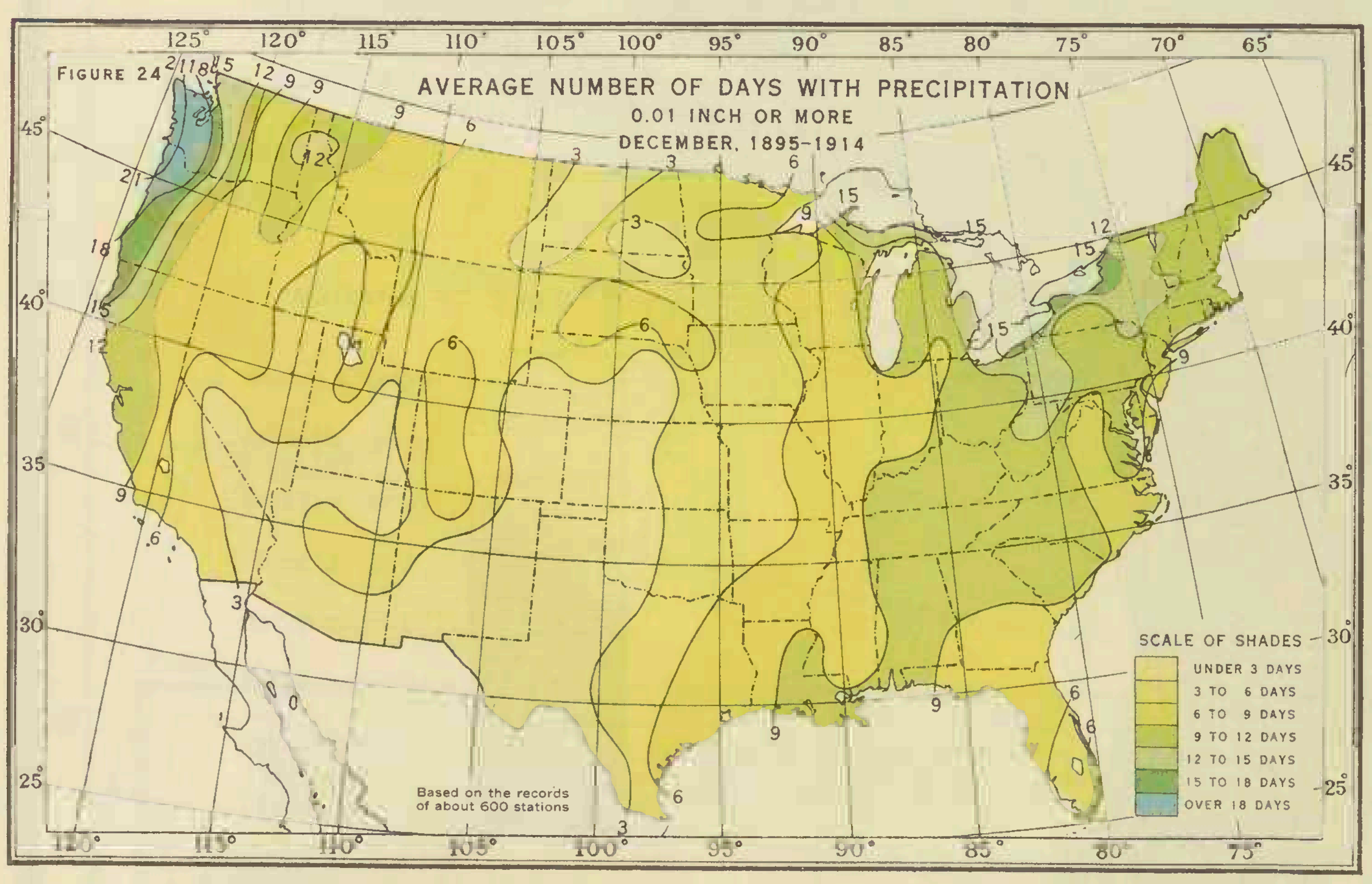
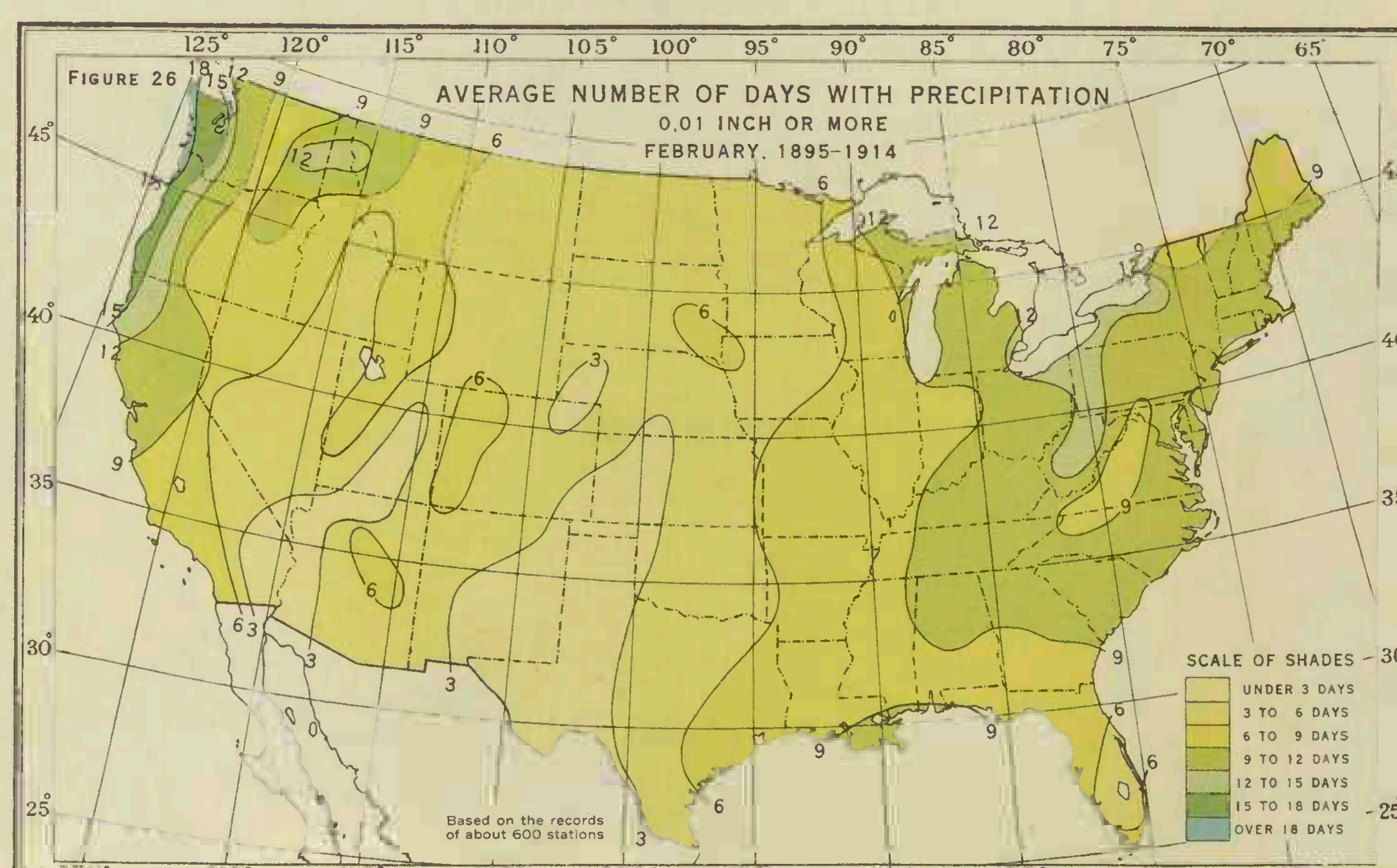
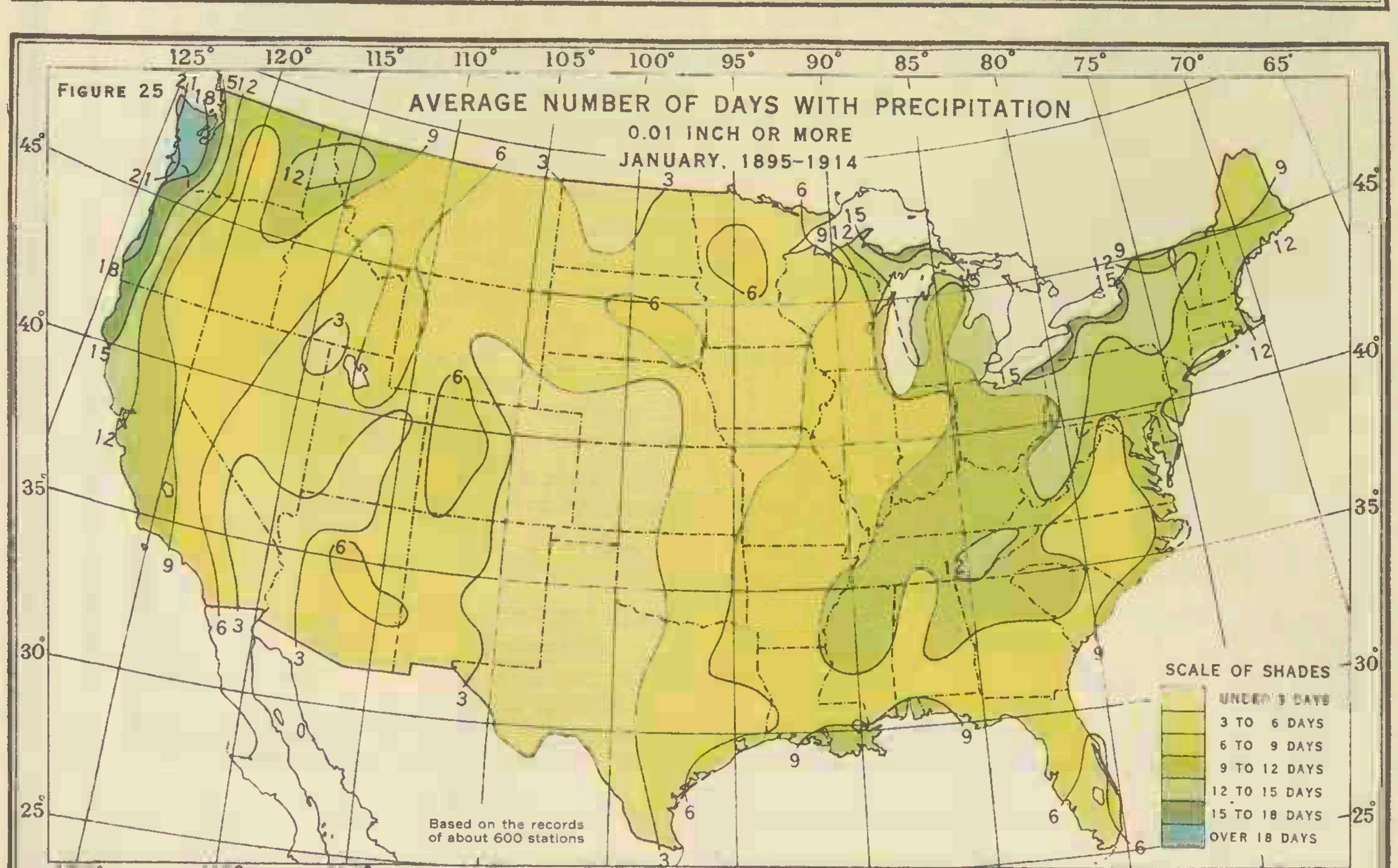
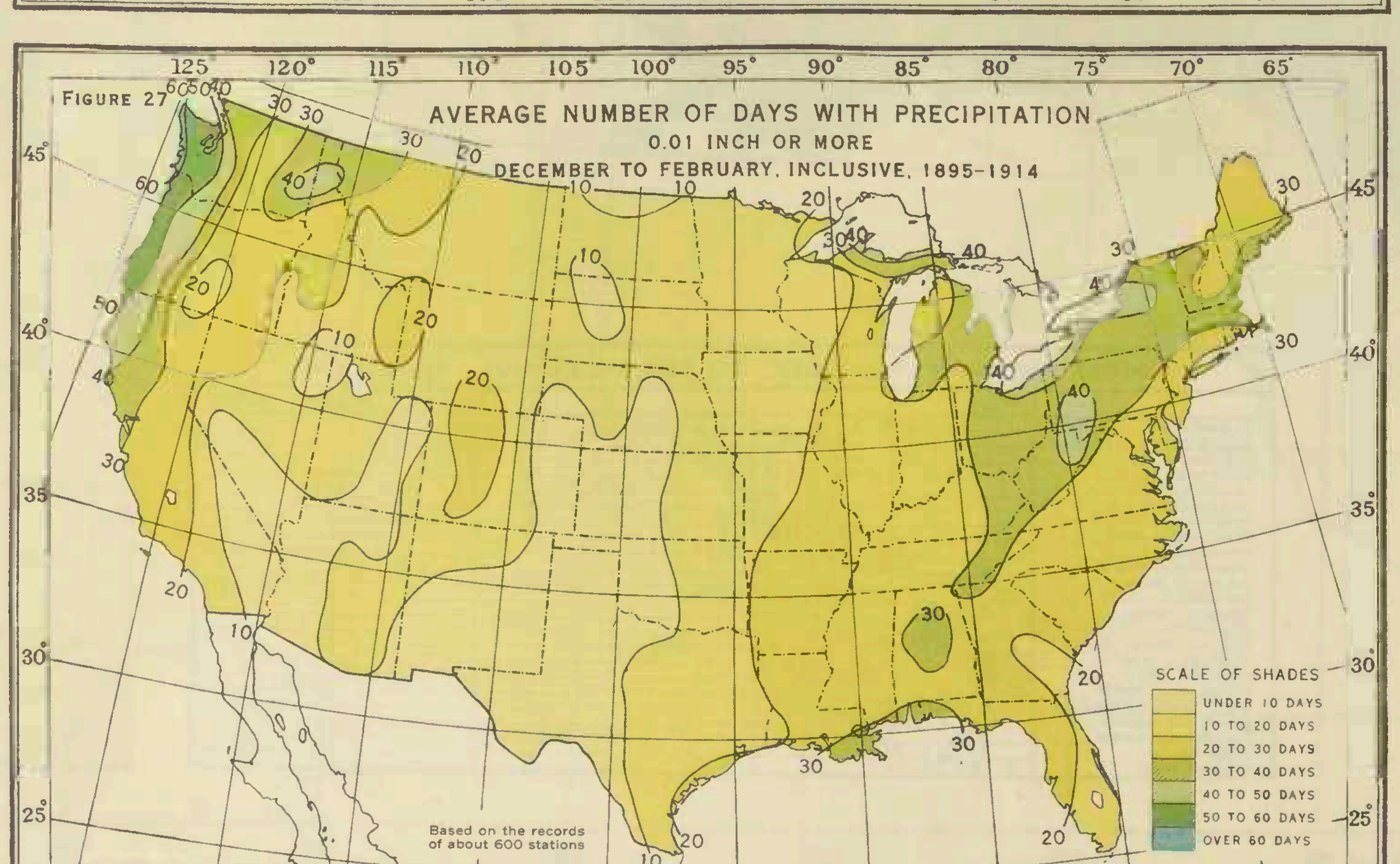


Figure 23.—The geographic distribution of precipitation in February does not differ materially from that in January, except that the amounts are usually somewhat smaller in the northern portions of the Pacific Coast States and markedly smaller in the central and southern portions. Likewise, precipitation is usually lighter for this month in the central and northern Rocky Mountain districts, but over the Plains region in February somewhat larger amounts occur than in January. However, precipitation continues light in this region, large areas receiving, on the average, less than 0.5 inch. In the central Gulf States and the southern Appalachian Mountain region precipitation in February is comparatively heavy, generally 5 to 6 inches or more, but in the Florida Peninsula the average amounts are small, ranging from 2 to slightly more than 3 inches.









Figures 24, 25, and 26 show the average number of days with precipitation (0.01 inch or more) for the months of December, January, and February, respectively, and Figure 27 shows the total number of days for the winter season. Along the North Pacific Coast during the months of December and January rain occurs, on the average, on about two-thirds of the days, and February has only slightly fewer rainy days. East of the Rocky Mountains the number of rainy days increases from about 3 for each month in the western portion of the Great Plains region to from 9 to 15 in most sections east of the Mississippi River. There is, however, a sharp falling off in the extreme southeast to less than 6 days each month in portions of the Florida Peninsula.

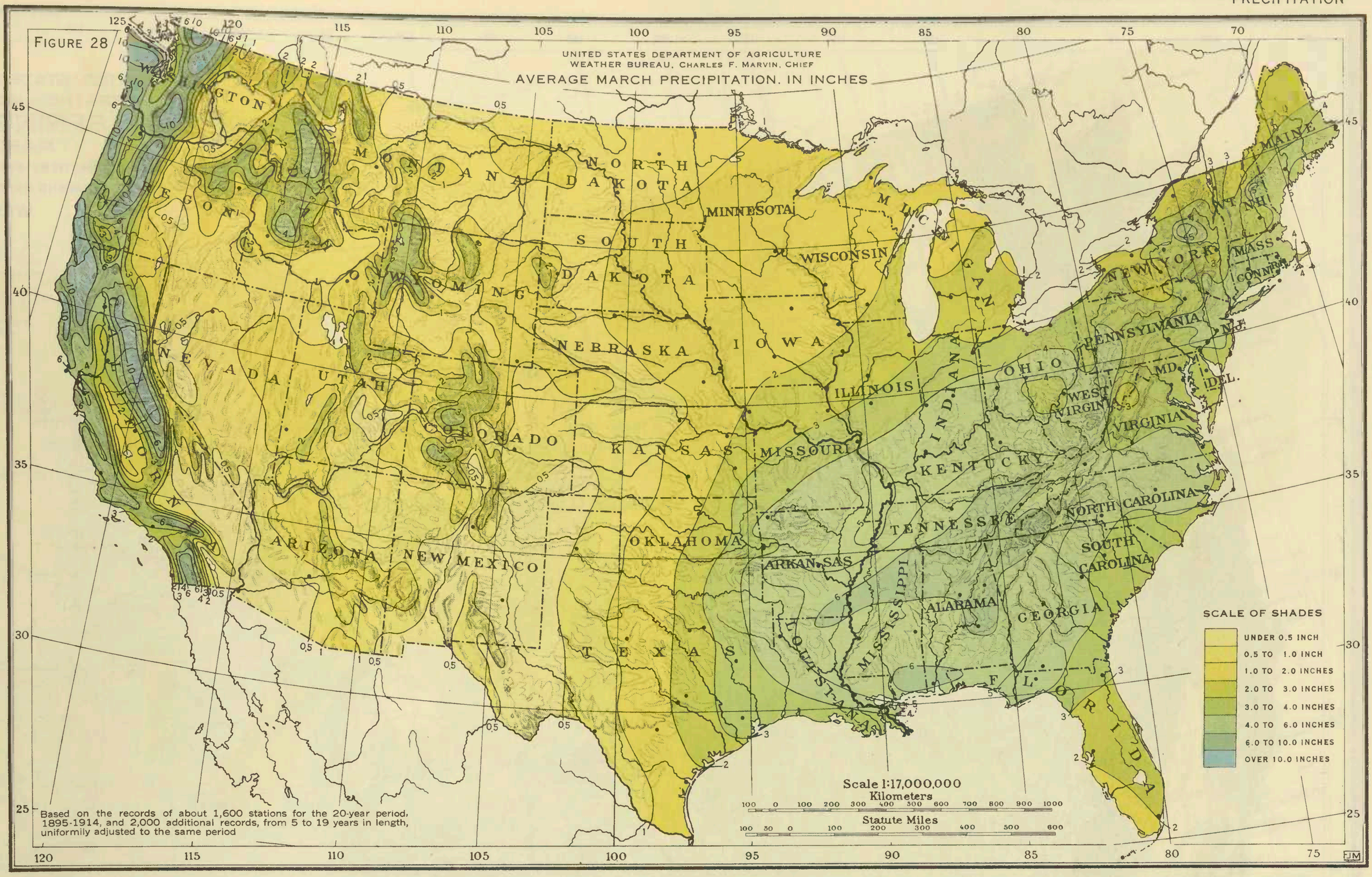


Figure 28.—At the higher altitudes of the Pacific Coast States precipitation continues heavy in March, with much snow in the mountains; in fact, at some places March is usually the month of heaviest snowfall. The average snowfall during March at Summit, Cal., is about 7 feet. Over the Interior Plateau region and at the higher altitudes in the Rockies the precipitation for March is usually about the same as that during the preceding month, but in the Great Plains region there is a rather marked increase, the March average ranging generally from 1 to 2 inches. In the States east of the Great Plains the averages range from 2 to 3 inches along the Canadian border to 6 inches or more over large areas from Tennessee southward, but over the Florida Peninsula usually less than 3 inches occur.

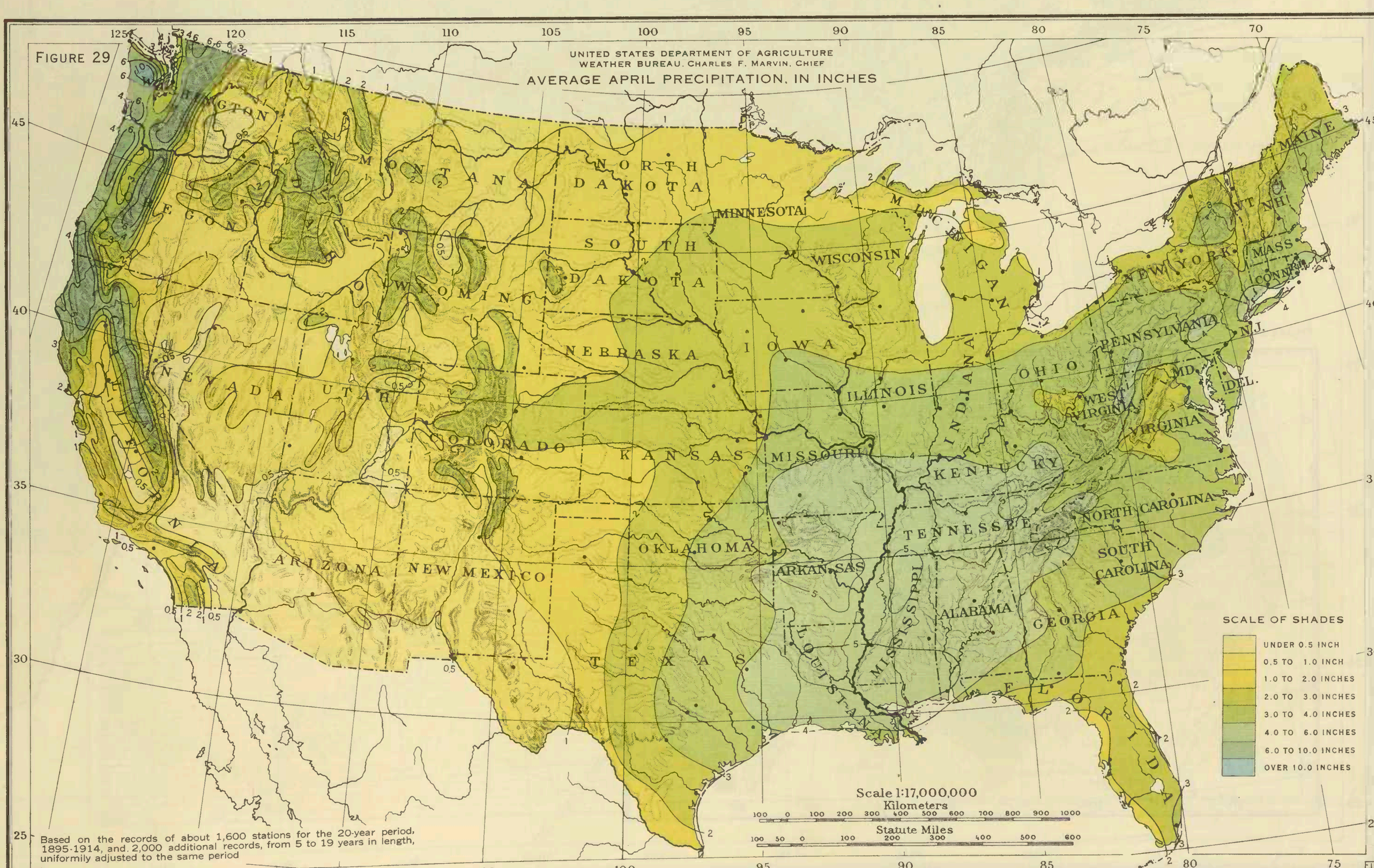


Figure 29.—West of the Continental Divide there is usually a marked decrease in the amount of precipitation received during April, except in the Central and Northern Plateau region, and, as a rule, much less snow occurs at the higher altitudes. The increase in precipitation in the eastern foothills of the Rocky Mountains and throughout the Plains States becomes pronounced during April, the monthly averages in some sections increasing to about 2.5 inches, as compared with less than 0.5 inch for a winter month. In most districts east of the prairie region, however, the April rainfall is usually less than for the preceding month, the averages in only comparatively small areas in the lower Mississippi Valley reaching as much as 5 inches. In the Florida Peninsula the rainfall continues scanty, averaging only about 2 inches.

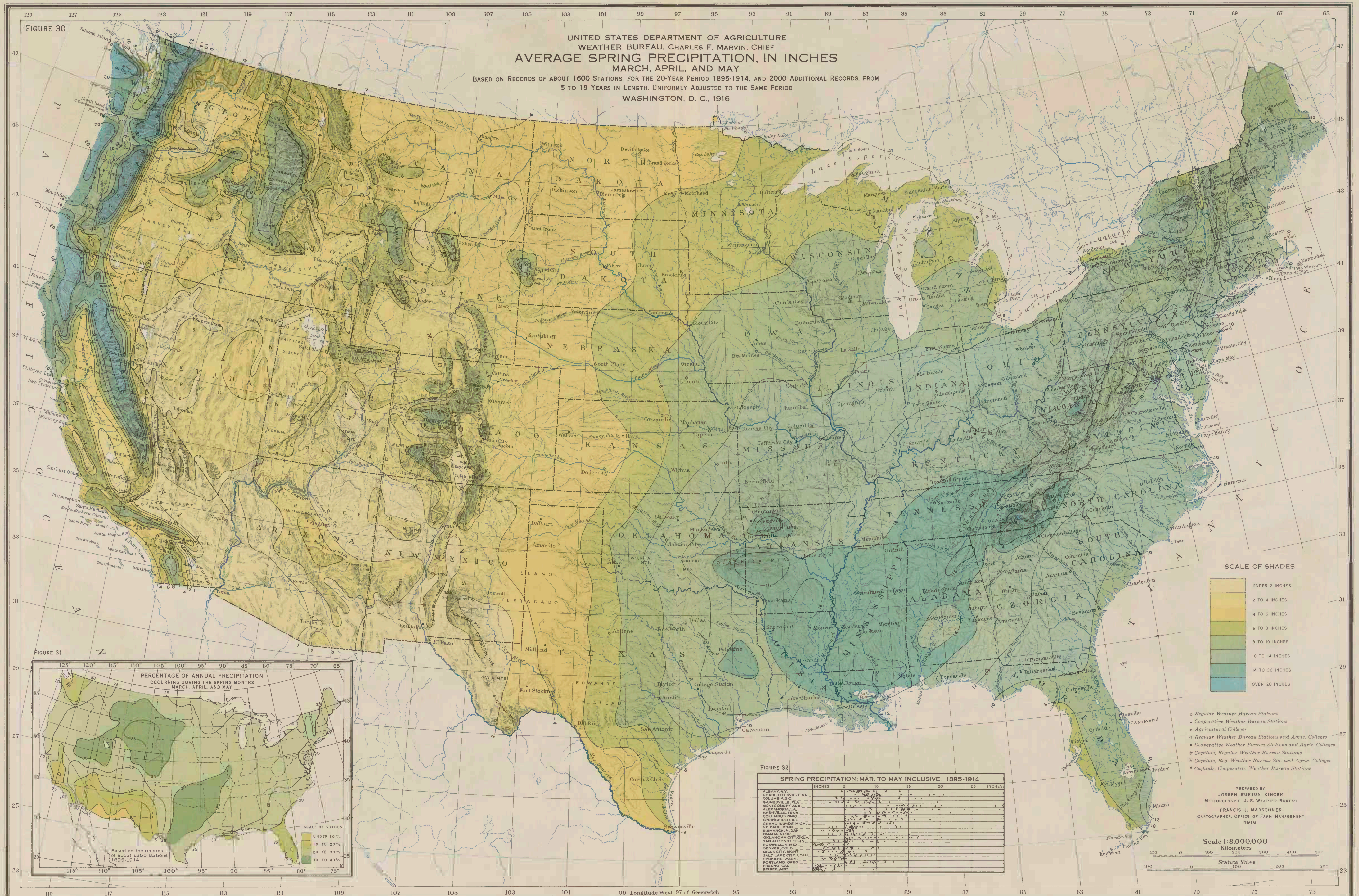


Figure 30.—This chart shows the average spring precipitation, March to May, inclusive. In the Pacific Coast States there is a marked diminution in the amount of precipitation during the spring months, except in the eastern portions of Washington and Oregon. There is also much less snowfall in the Rocky Mountain region. Over the Great Plains region precipitation increases rapidly with the advent and advance of spring, the total for the three spring months being much larger than for the winter. East of Lake Michigan and the Mississippi River there is in most districts no noteworthy difference in the amount of precipitation received during the spring months and that received in the winter season.

Figures 31 and 32.—The inset chart in the lower left-hand corner shows the percentage of the annual precipitation that occurs during the spring months. The proportion is largest in the western portions of Nebraska and South Dakota and in the adjacent Rocky Mountain States, where from 30 to 35 per cent or more, of the annual precipitation is received during the spring. The graph at the bottom to the right shows for a number of representative stations, well distributed over the country, the total spring precipitation that occurred in each of the 20 years whose record was used in preparing the large chart. It indicates the characteristics of distribution and variations from year to year in different localities.

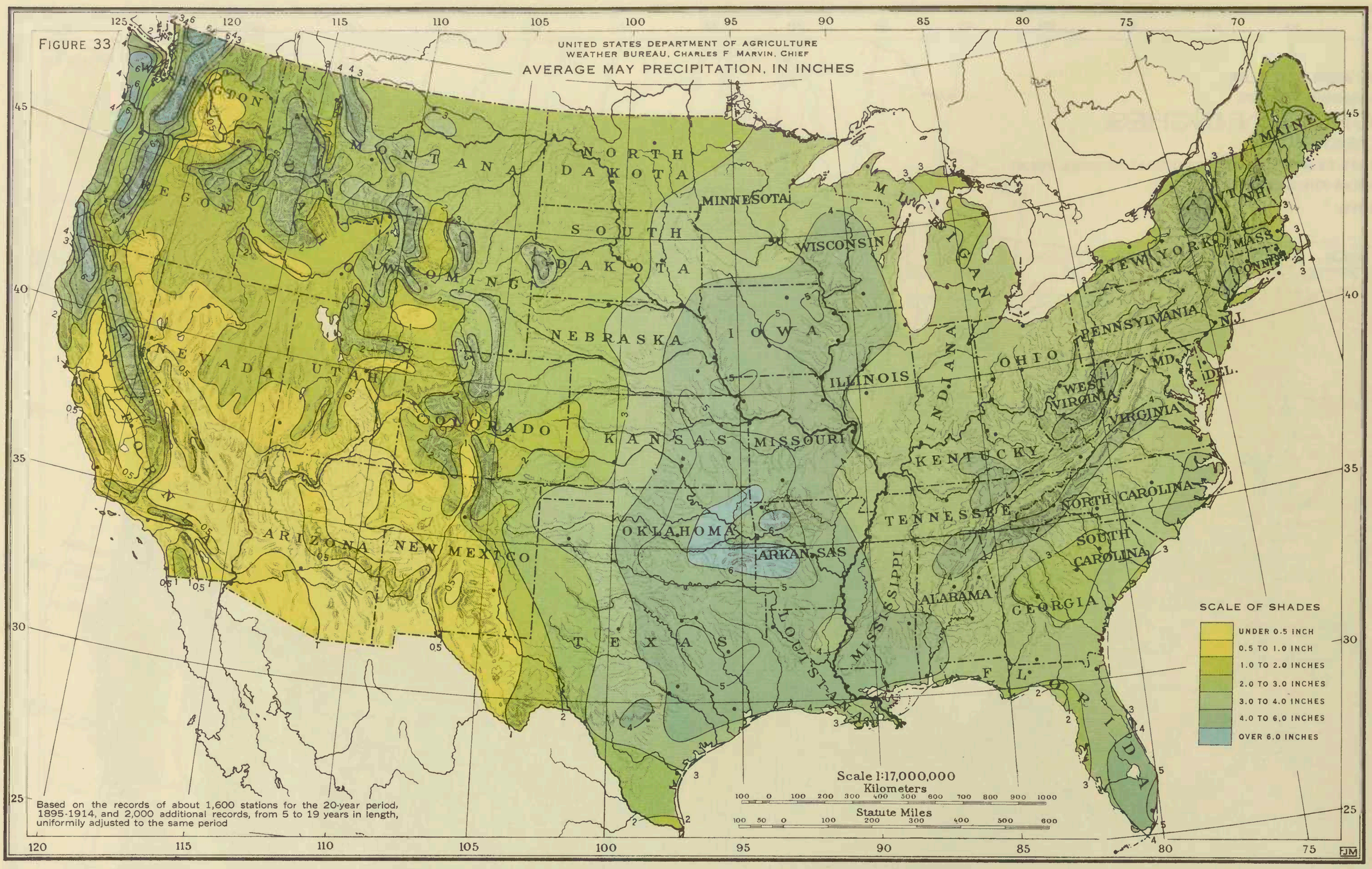
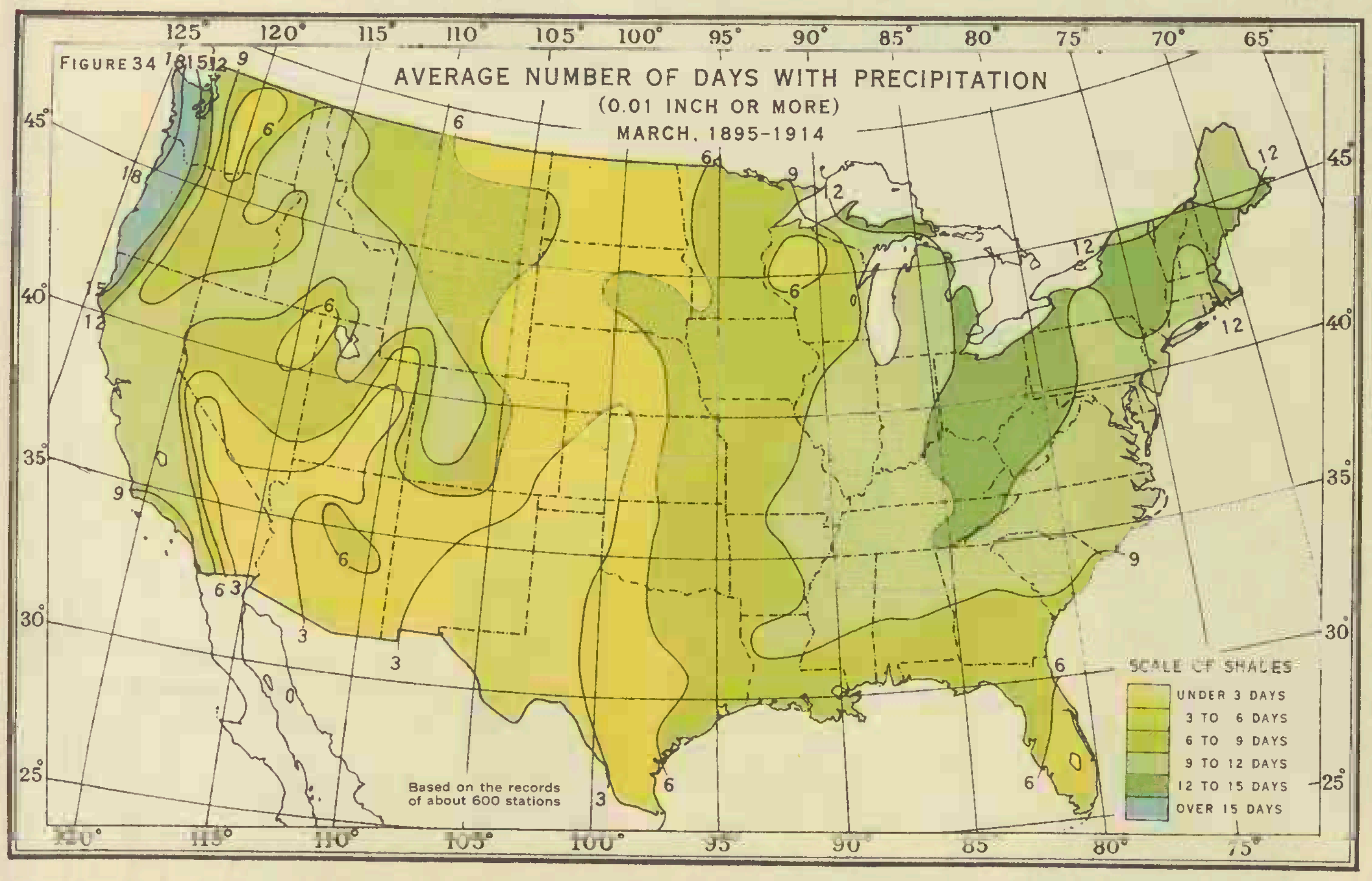
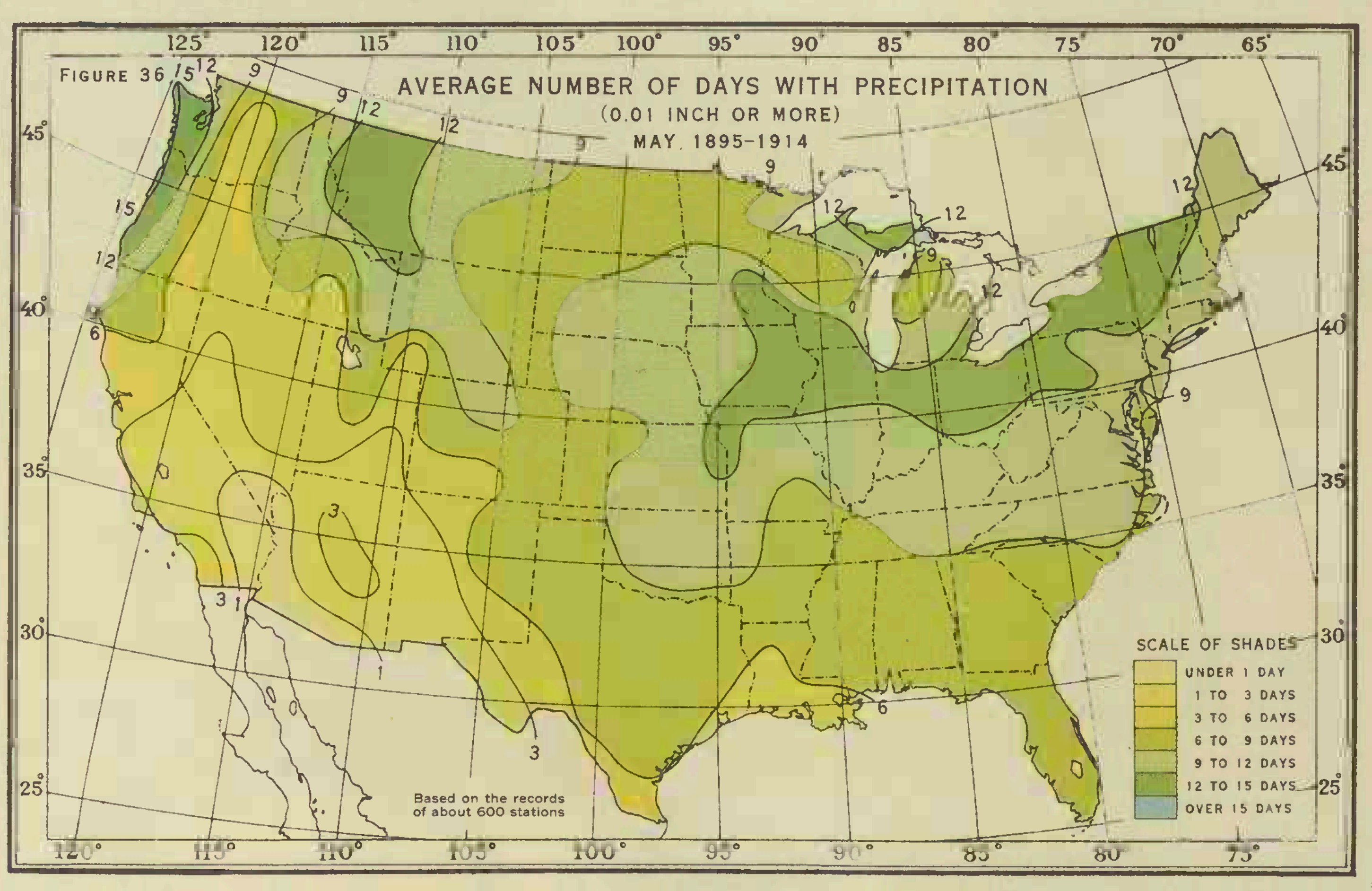
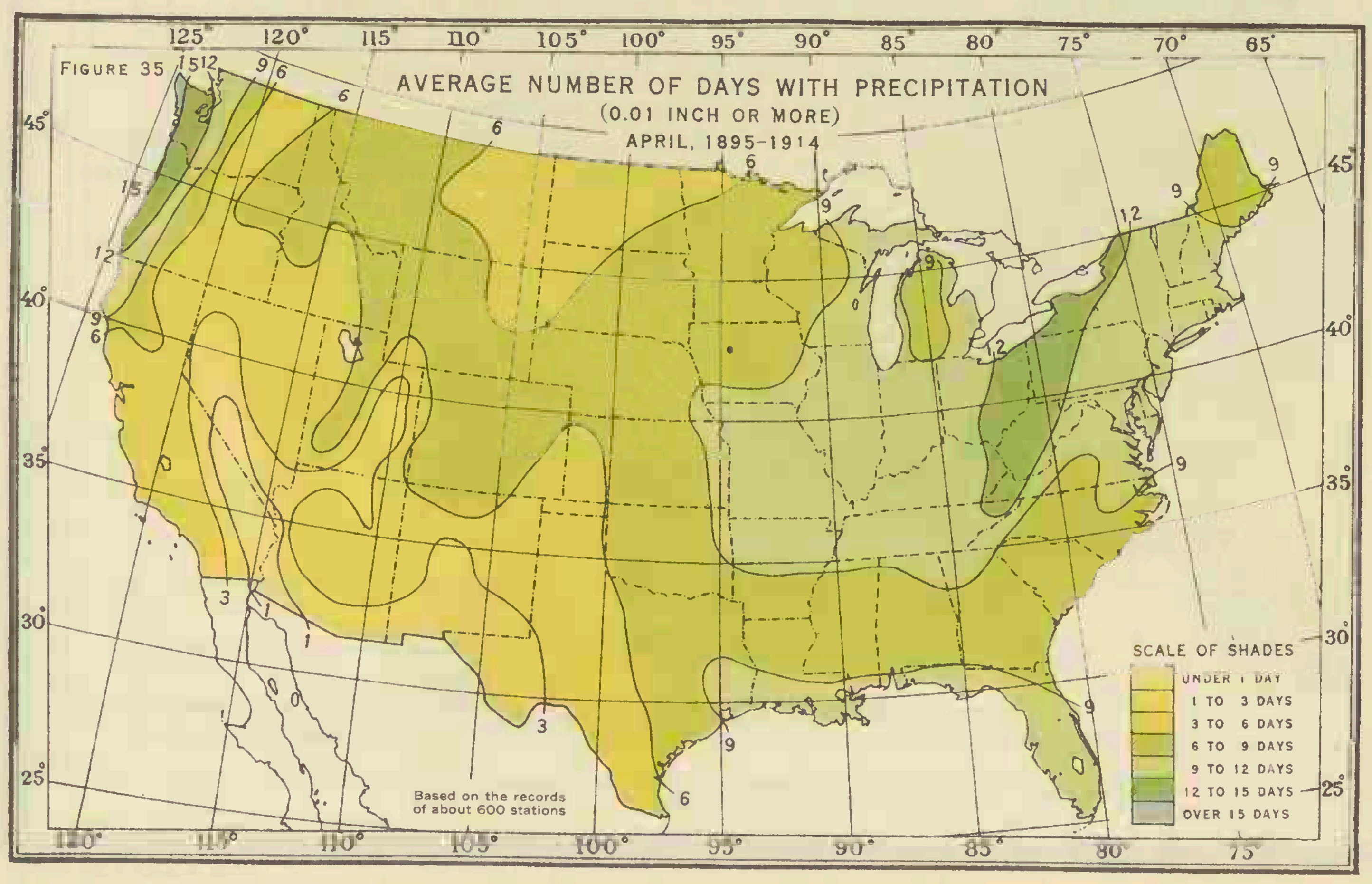
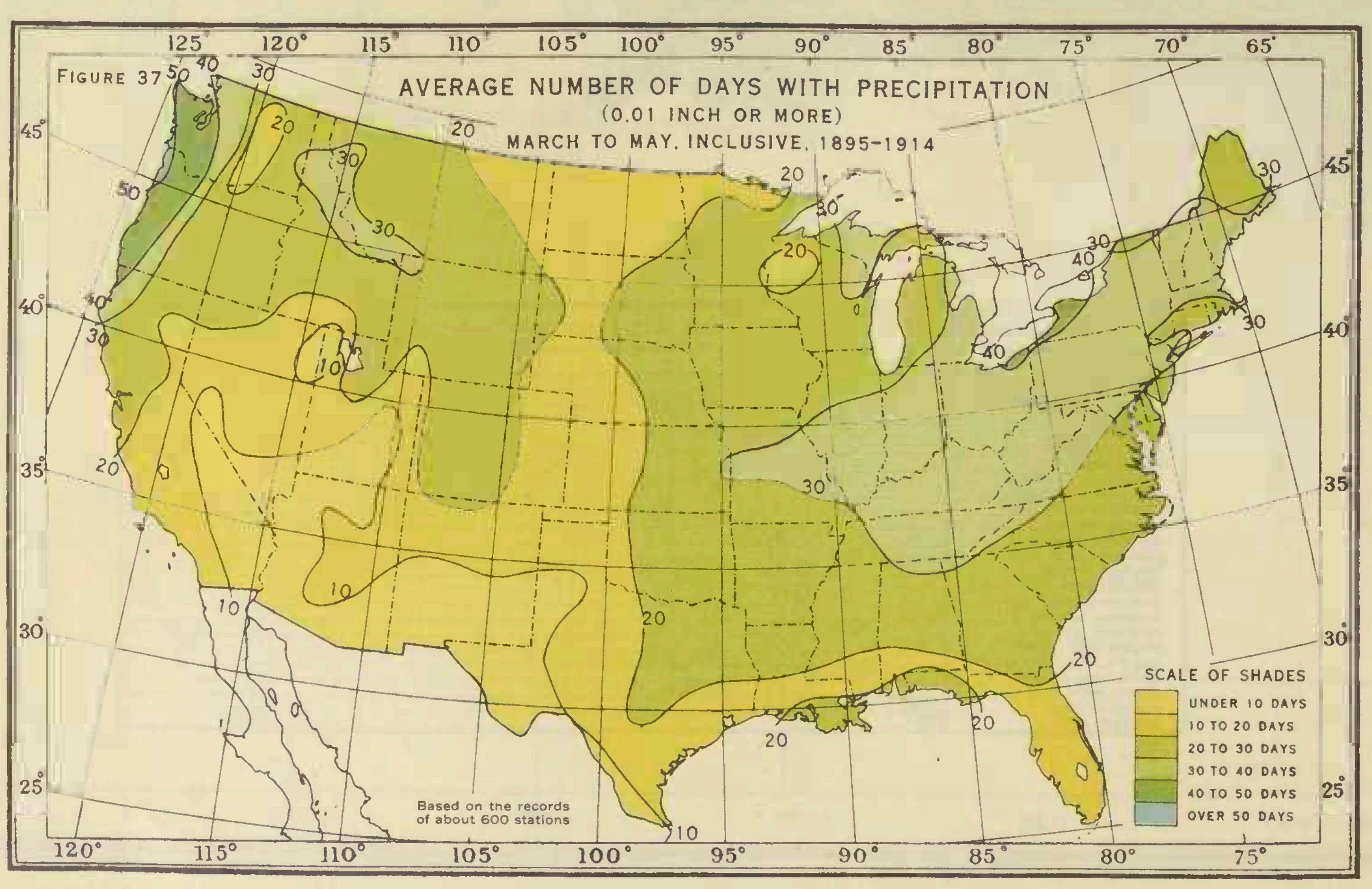


Figure 33.—West of the Sierra Nevada and Cascade ranges in the Pacific Coast States precipitation continues to diminish during the month of May, but throughout the central and northern portions of the Interior Plateau and Rocky Mountain regions and on the Great Plains there is a rather marked increase over the preceding month. The outstanding feature of the geographic distribution of precipitation for May is the comparatively large amount received in the central and eastern portions of Kansas and Oklahoma and the western portions of Arkansas and Missouri, where the rainfall during this month averages 5 to 6 inches, or more, and is larger than in any other agricultural section of the country. This is also the region of greatest thunderstorm activity for the month, the average number of days on which thunderstorms occur being about 8. Throughout the regions east of the Mississippi River the average precipitation in May is much more uniform than in the preceding months, ranging generally from about 3 to slightly more than 4 inches.









Figures 34, 35, and 36 show the average number of days with precipitation (0.01 inch or more) for the months of March, April, and May, respectively, and Figure 37 shows the total number for the spring season. Along the North Pacific Coast rainfall is less frequent during the spring months than during the winter, precipitation occurring, as a rule, on about one-half the days. In the Plains region there is a marked increase in rainfall frequency with the advent of spring, rain occurring, on the average, from 6 to 9 days each month during March and April, with somewhat greater frequency during May. East of the Mississippi River the number of rainy days for the spring season as a whole ranges from about 20 along the Gulf Coast to about 40 in portions of the Great Lakes region.

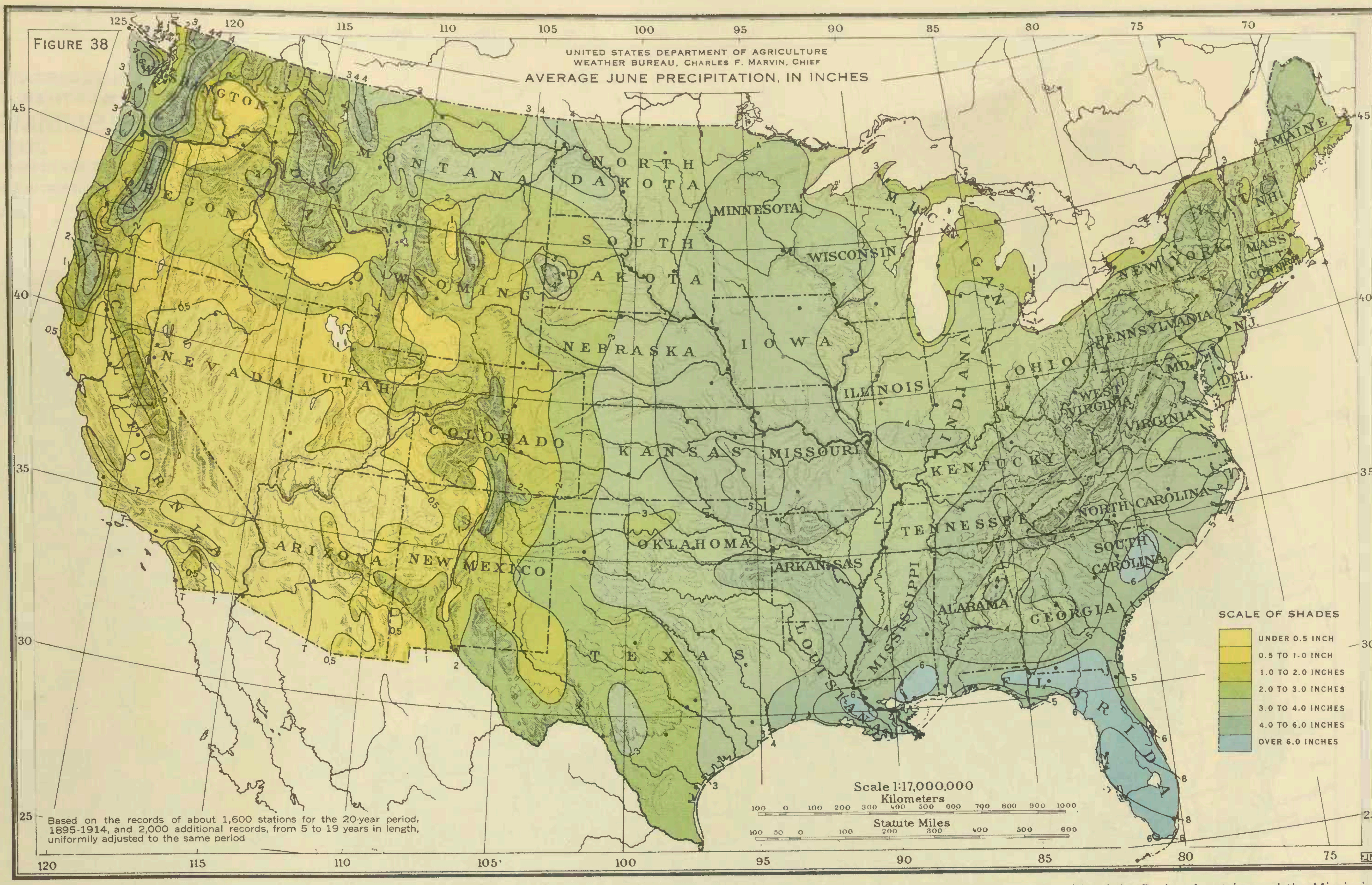


Figure 38.—The most noteworthy feature of the geographic distribution of the June rainfall is the relatively large amount received between the eastern foothills of the Rocky Mountains and the Mississippi River as compared with the annual amount in that region. In most of this area the June rainfall ranges from 3 to 5 inches, being 15 to 20 per cent of the annual amount. East of the Mississippi River the rainfall for the month ranges from about 3 inches along the Canadian border to from 6 to 8 inches near the Gulf Coast. The heaviest rainfall for June usually occurs in the Florida Peninsula, in portions of which more than 8 inches are received on the average, which is in marked contrast to the several preceding months with comparatively little rainfall. From the Rocky Mountains westward precipitation for June is usually scanty, except that 3 to 4 inches, or more, occur, on the average, at the higher altitudes in the northern districts. In the central and southern sections of the Pacific Coast States the dry season is on and the rainfall is negligible in amount, except for occasional showers in the mountains.

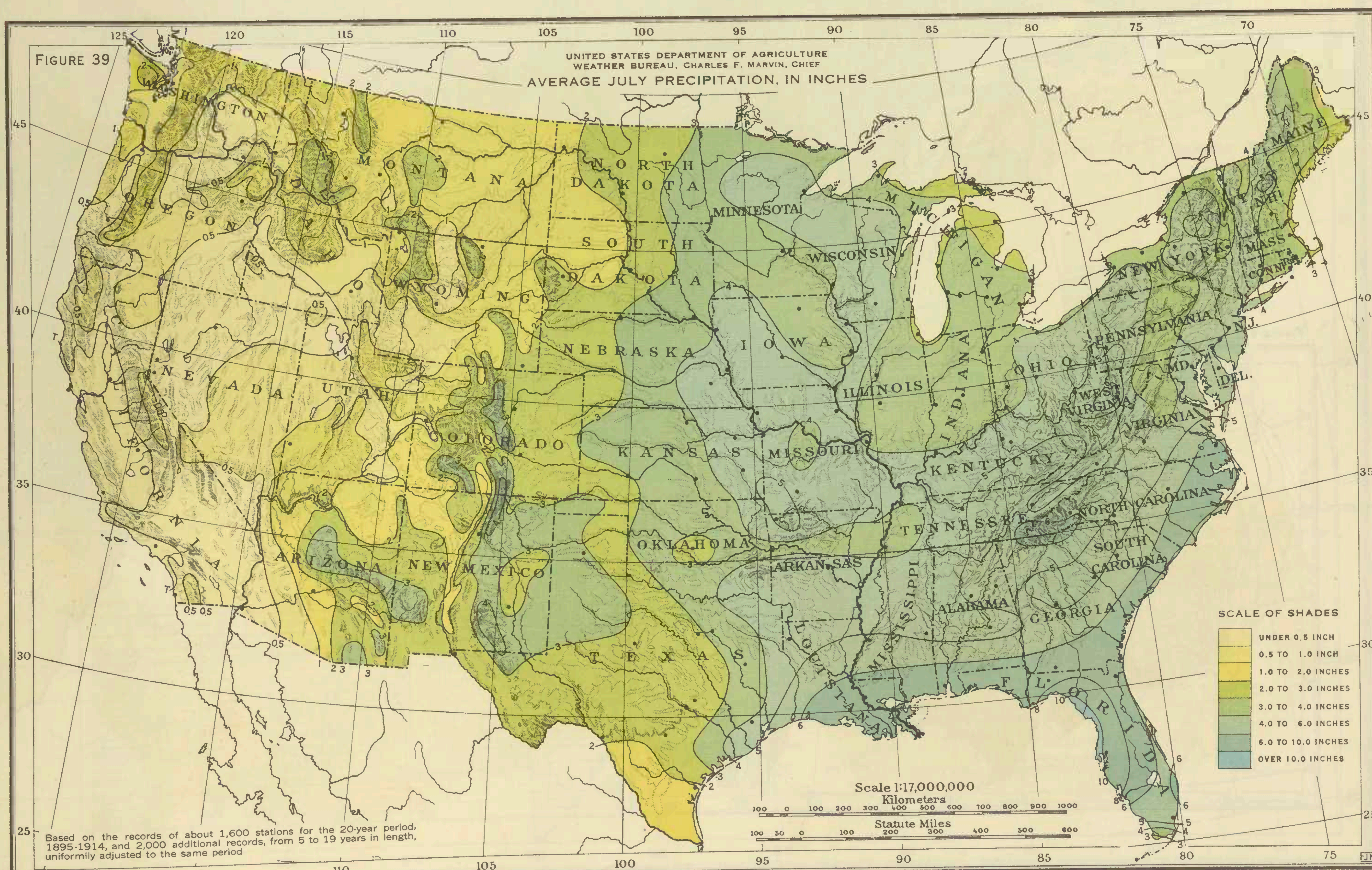


Figure 39.—July rainfall results largely from local thunderstorms, which are more numerous in this than in any other month. The region of the greatest activity is found along the west coast of the Florida Peninsula, where thunderstorms usually occur on more than 20 days of the month, and here the average rainfall for the month ranges from 8 to 10 inches, or more, being heavier than in any other section of the country. Over much of the Great Plains the average July rainfall is appreciably less than for June, but to the eastward there is in general an increase in amount over the preceding month. In the southwestern region, including western Texas, New Mexico, and most of Arizona, July is usually the wettest month of the year, but in the Pacific Coast States the dry season is at its height. No rain is expected in California, except for an occasional local shower in the mountains, and farther north, in Washington and Oregon, but little rain occurs.

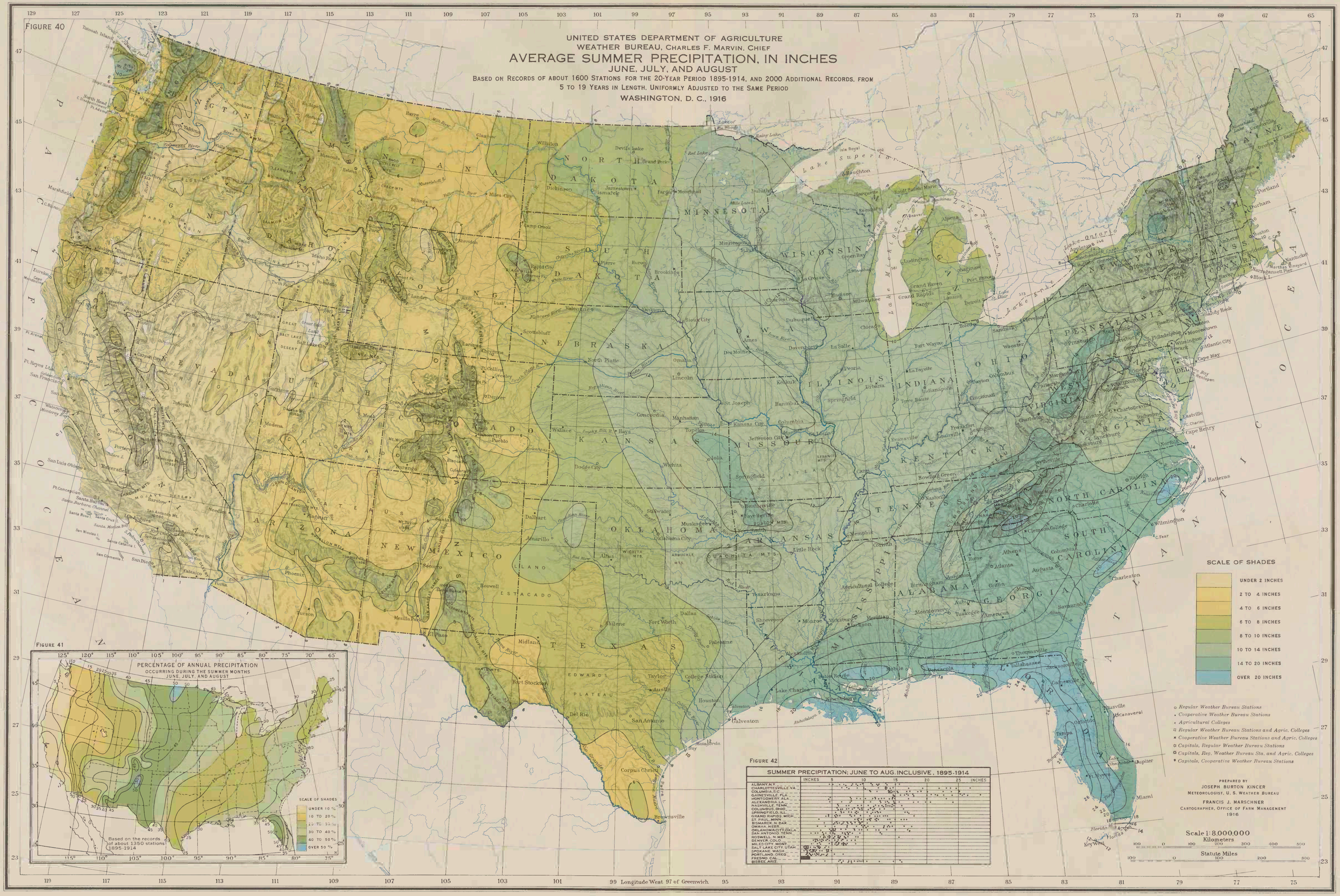


Figure 40.—This chart shows the average summer precipitation, June to August, inclusive. In the Pacific Coast States the summer is almost rainless except in the more northern sections, where showers may be expected to occur occasionally, especially in the mountains. In the Plains States precipitation in the summer season continues comparatively heavy, and in New Mexico and eastern Arizona much of the annual precipitation occurs during the summer months, mostly in July and August. Along the Central and East Gulf and South Atlantic coasts rainfall is heavy during this season, the totals for the three months ranging from 16 to 25 inches, and it is comparatively heavy also in portions of the Appalachian Mountain region, where locally the summer totals reach as much as 20 inches.

Figures 41 and 42.—The inset chart in the lower left-hand corner shows the percentage of the annual precipitation that occurs during the summer months. In the central and northern Plains States from 45 to 50 per cent of the annual precipitation occurs during this season of the year, but in the Pacific Coast States little rain occurs during the summer months, much of California receiving, on the average, less than 1 per cent of the annual amount. The graph to the right shows for a number of representative stations, well distributed over the country, the total summer precipitation that occurred in each of the 20 years whose record was used in preparing the map. It indicates the characteristics of distribution and variations from year to year in different localities.

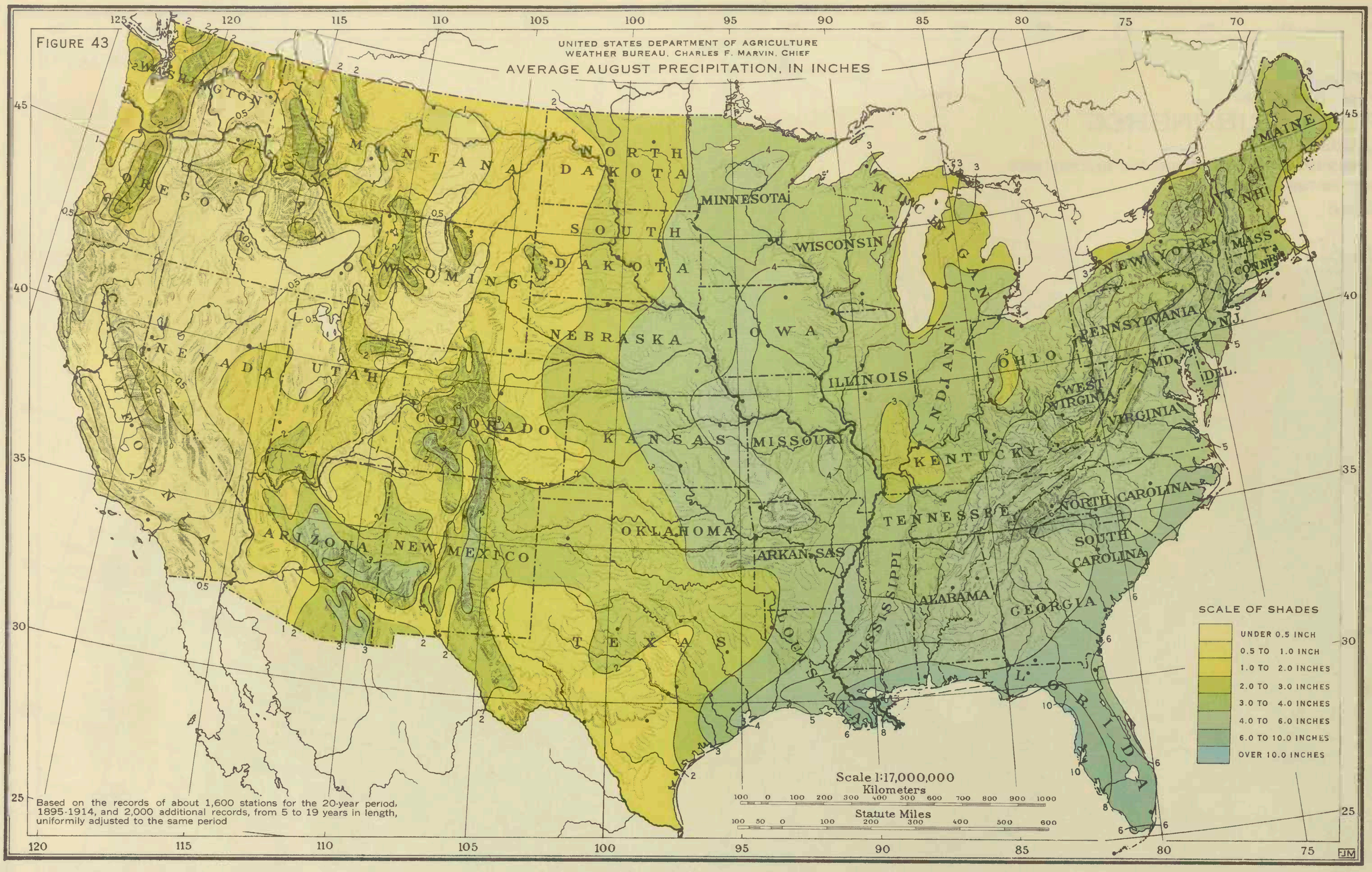
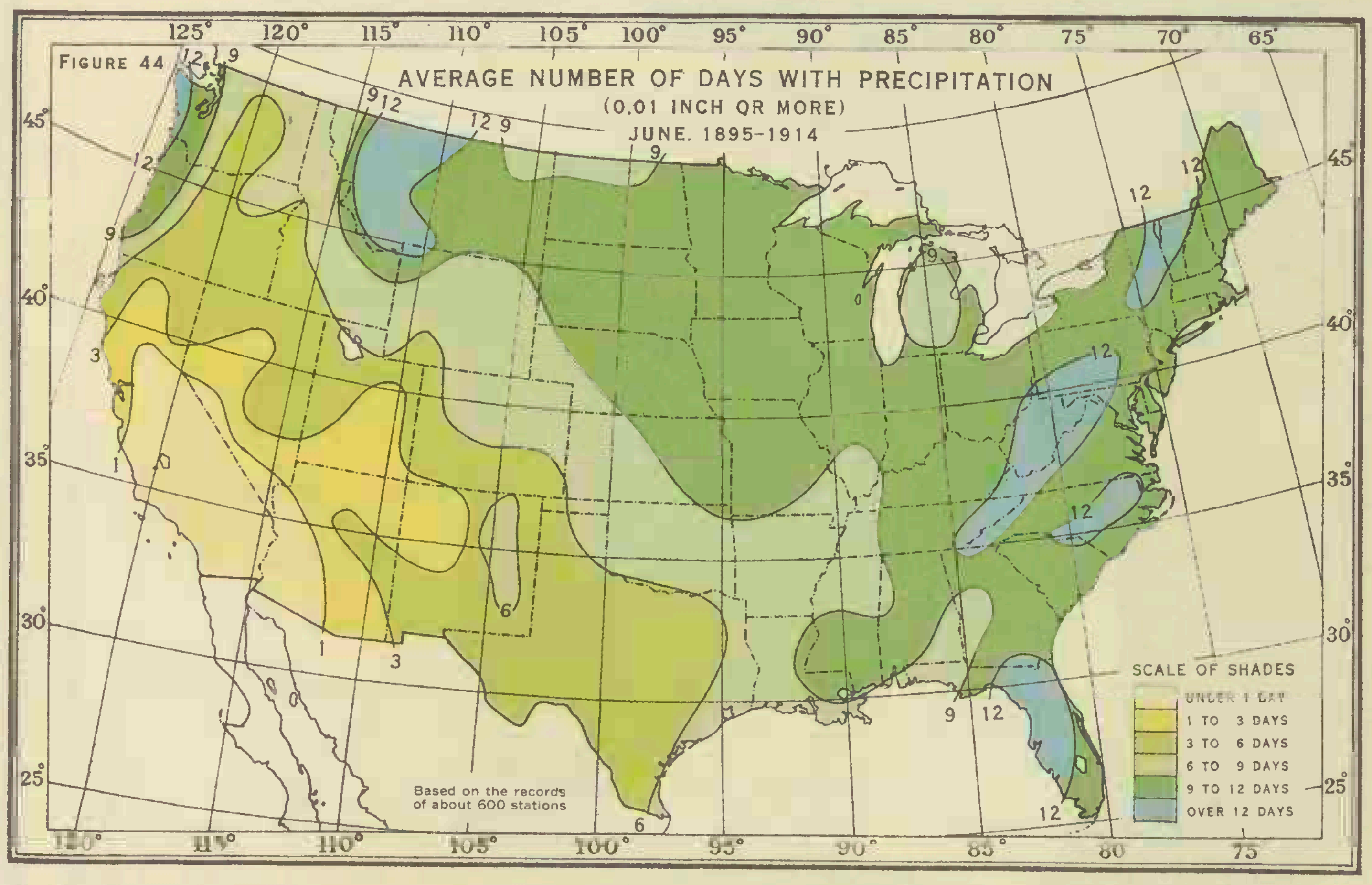
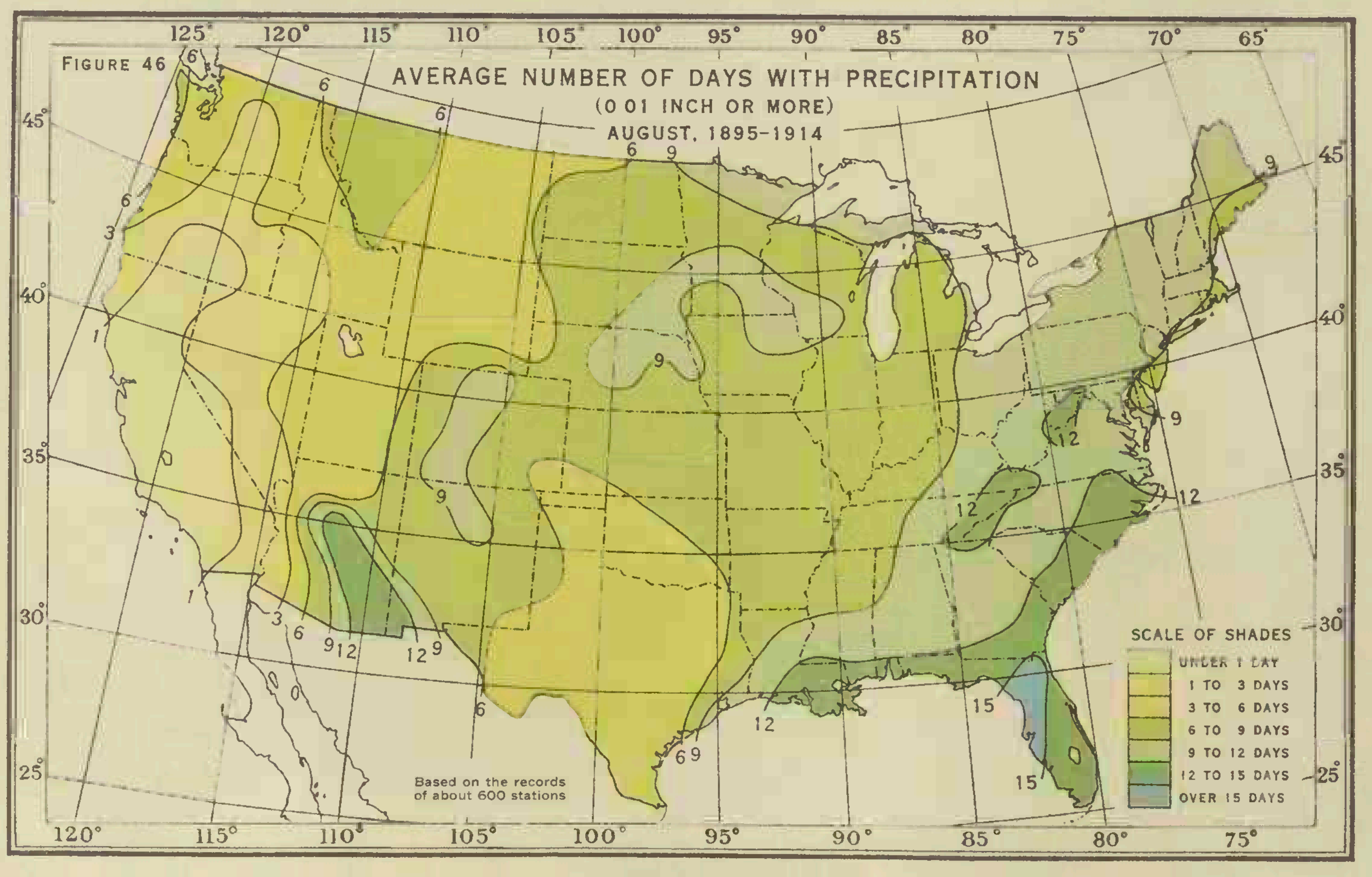
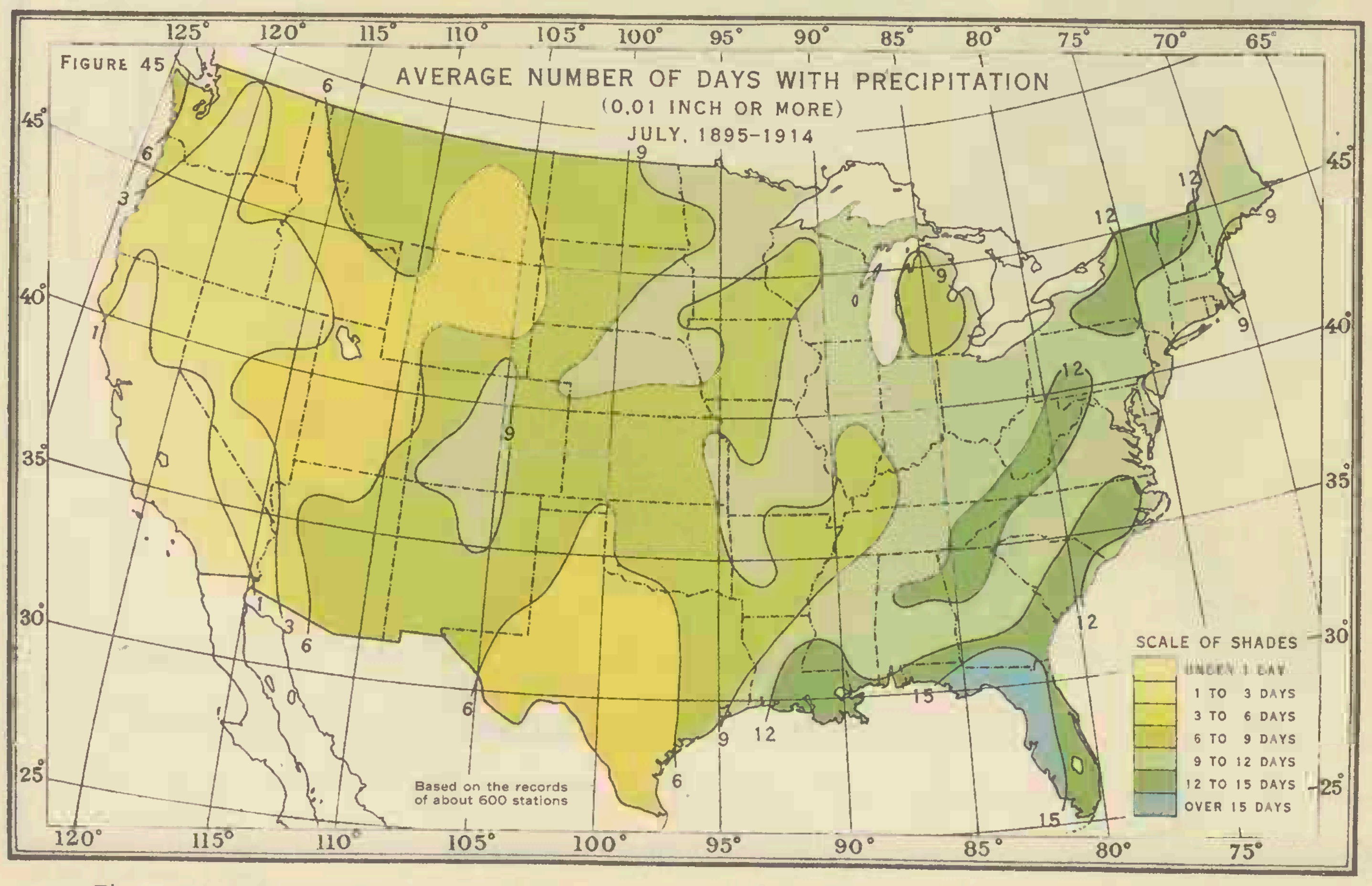
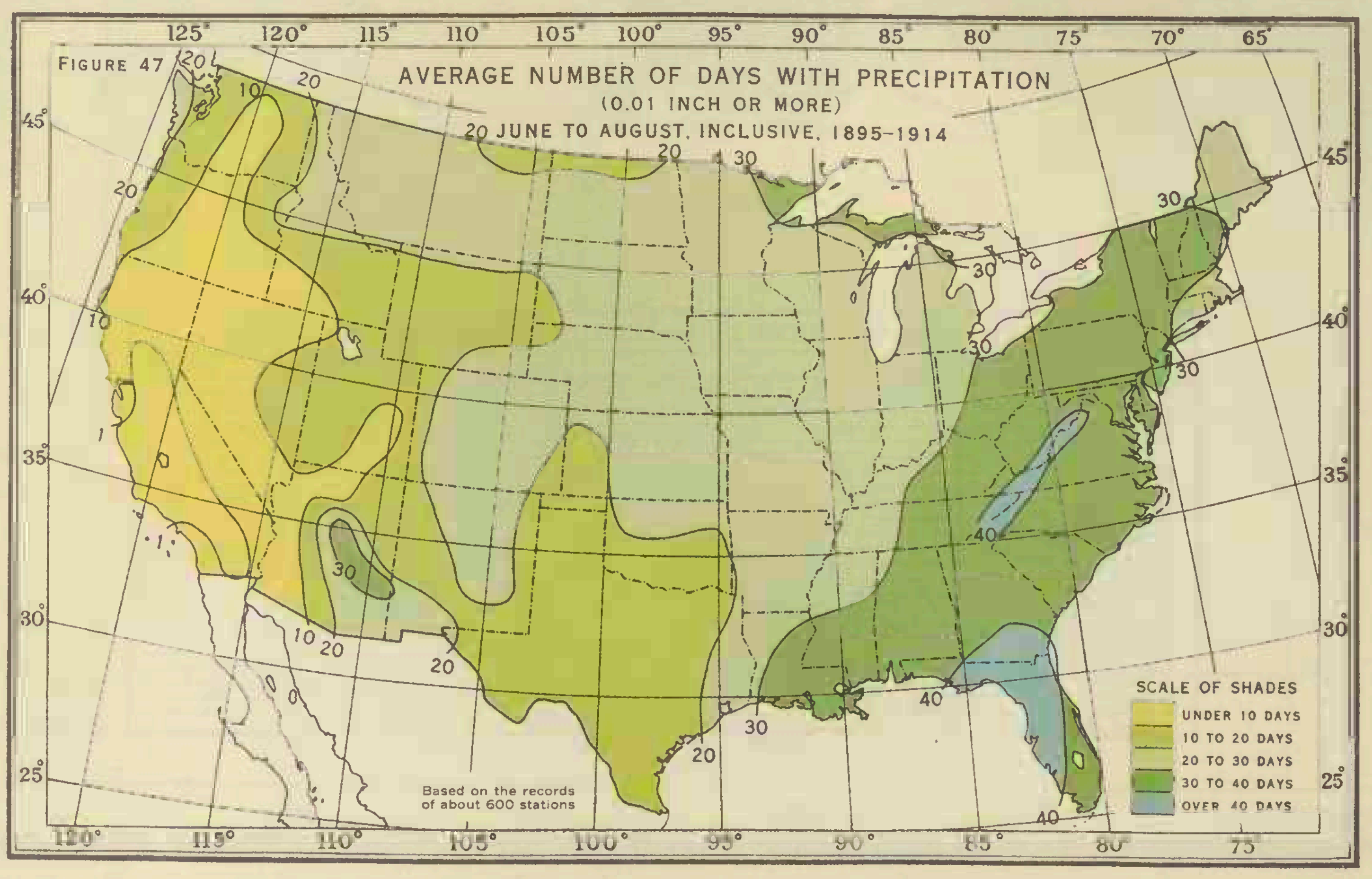


Figure 43.—In August, as in July, rainfall is largely the result of thunderstorms, and the region of their greatest frequency, as well as that of heaviest precipitation, is found in portions of the Southeastern States, where the average rainfall for the month ranges from 6 to 10 inches. In general the geographic distribution of precipitation for August does not differ materially from that of July, although in portions of the Plains States the amounts are usually somewhat less in August. In most of New Mexico and Arizona the rainfall for August is comparatively heavy, this and the preceding month constituting the rainy season in that region. Elsewhere west of the Rocky Mountains the August rainfall, like that for July, is agriculturally unimportant.









Figures 44, 45, and 46 show the average number of days with precipitation for the months of June, July, and August, respectively, and Figure 47 shows the total number for the summer season. This is the dry season in the Pacific Coast States and rainfall is infrequent. Rain occurs on the average on less than one day during the entire season at the lower elevations in California, but the number of rainy days increases northward to about 20 for the season along the North Pacific Coast. East of the Rocky Mountains the number of rainy days for the three summer months increases from between 20 and 30 in most of the Plains region to about 40 in the central Appalachian Mountain region and in the extreme Southeast.

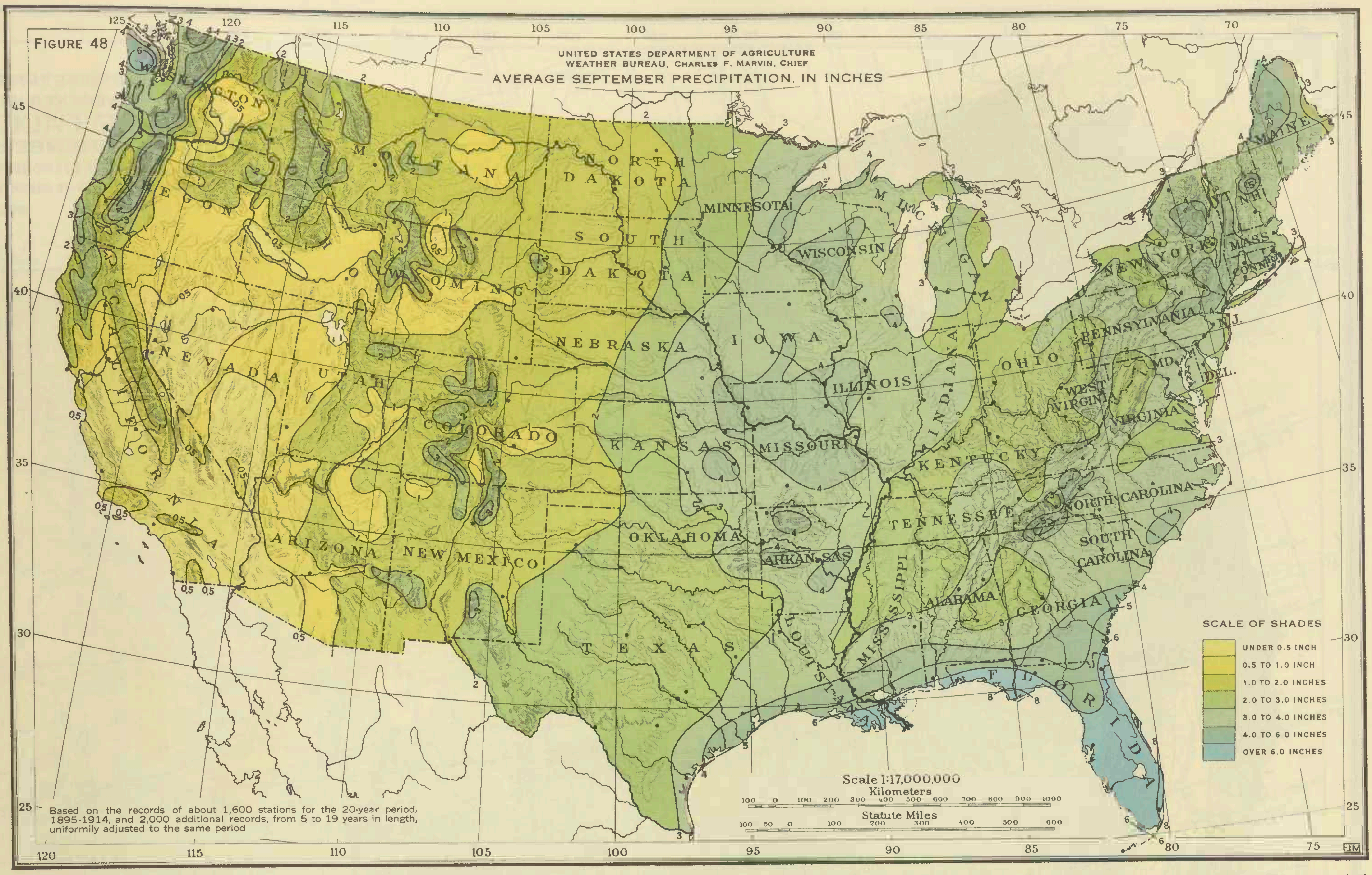


Figure 48.—With the advent of autumn the rainfall east of the Rocky Mountains in general becomes appreciably less, but in a few districts it is somewhat greater, notably in portions of the middle Mississippi and lower Missouri valleys, where the average September rainfall is slightly more than 4 inches, and along the southeastern coast of the Florida Peninsula, where it reaches 8 inches. The Florida Peninsula and the central and eastern Gulf coasts constitute the region of maximum September rainfall, receiving on the average from 6 to 8 inches; but the amounts decrease rapidly to the northward, where large areas usually receive less than 3 inches. In New Mexico and Arizona September rainfall is usually much less than that of August; but on the North Pacific Coast there is a marked increase, the averages ranging from 4 to 6 inches as compared with 1 to 2 inches for the preceding month.

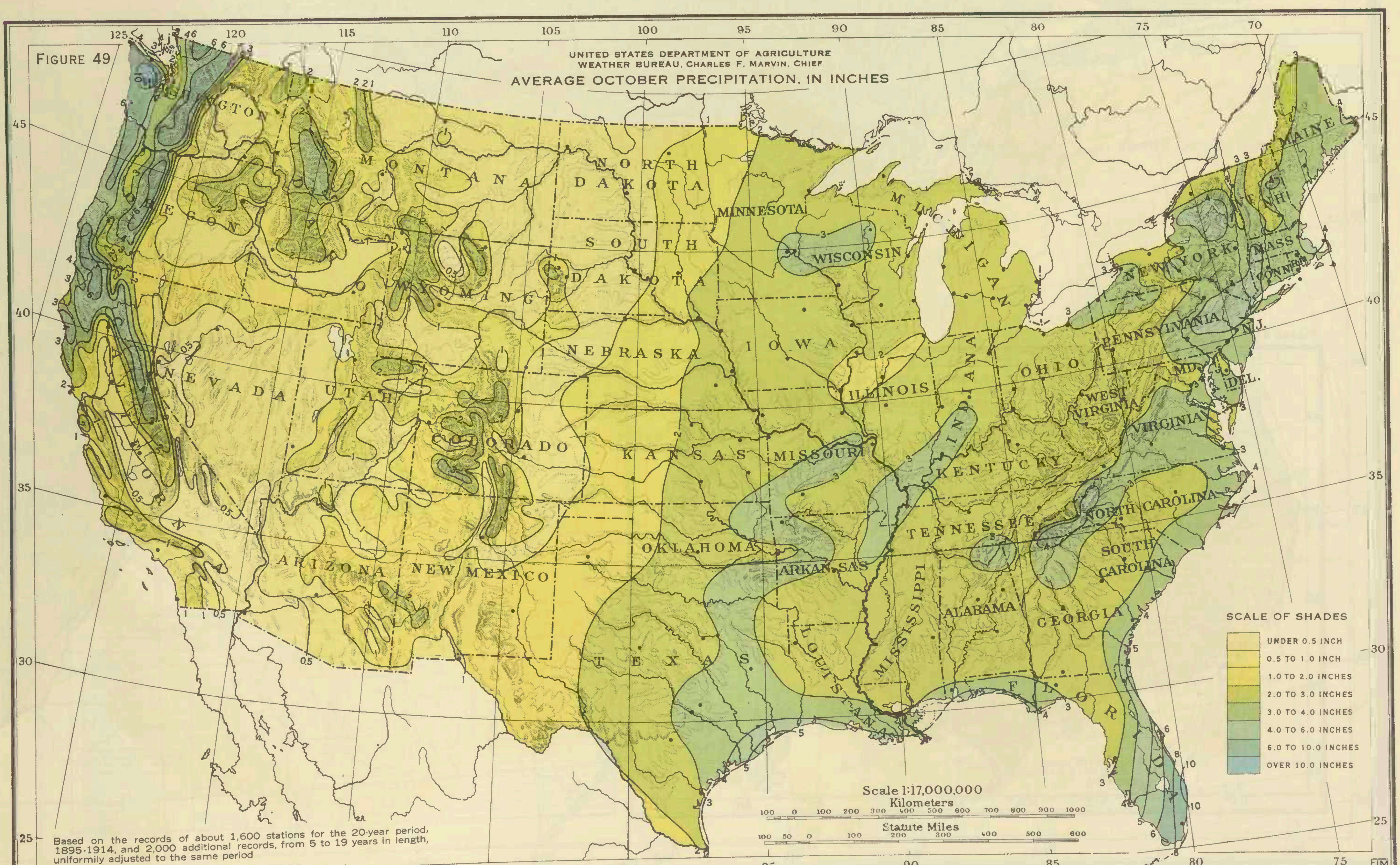


Figure 49.—East of the Rocky Mountains precipitation for October is usually considerably less than for the months immediately preceding. The decrease in precipitation in these central and eastern districts usually begins during the month of August, becomes more pronounced in September, and continues throughout October. The most noteworthy diminution from September to October occurs along the central and eastern Gulf coasts, where the October averages range from 3 to 4 inches, being only about one-half as large as in September. Likewise the falling off is rather pronounced in the middle and upper Mississippi and lower Missouri valleys, as well as over the Plains States. From the Rocky Mountains westward precipitation for October, as a rule, does not differ materially from that for September, except in the Pacific Coast region, where rains become more frequent with the advance of fall, especially in the northern portion, and at the higher altitudes. In these districts the October precipitation reaches 6 to 10 inches.

FIGURE 50

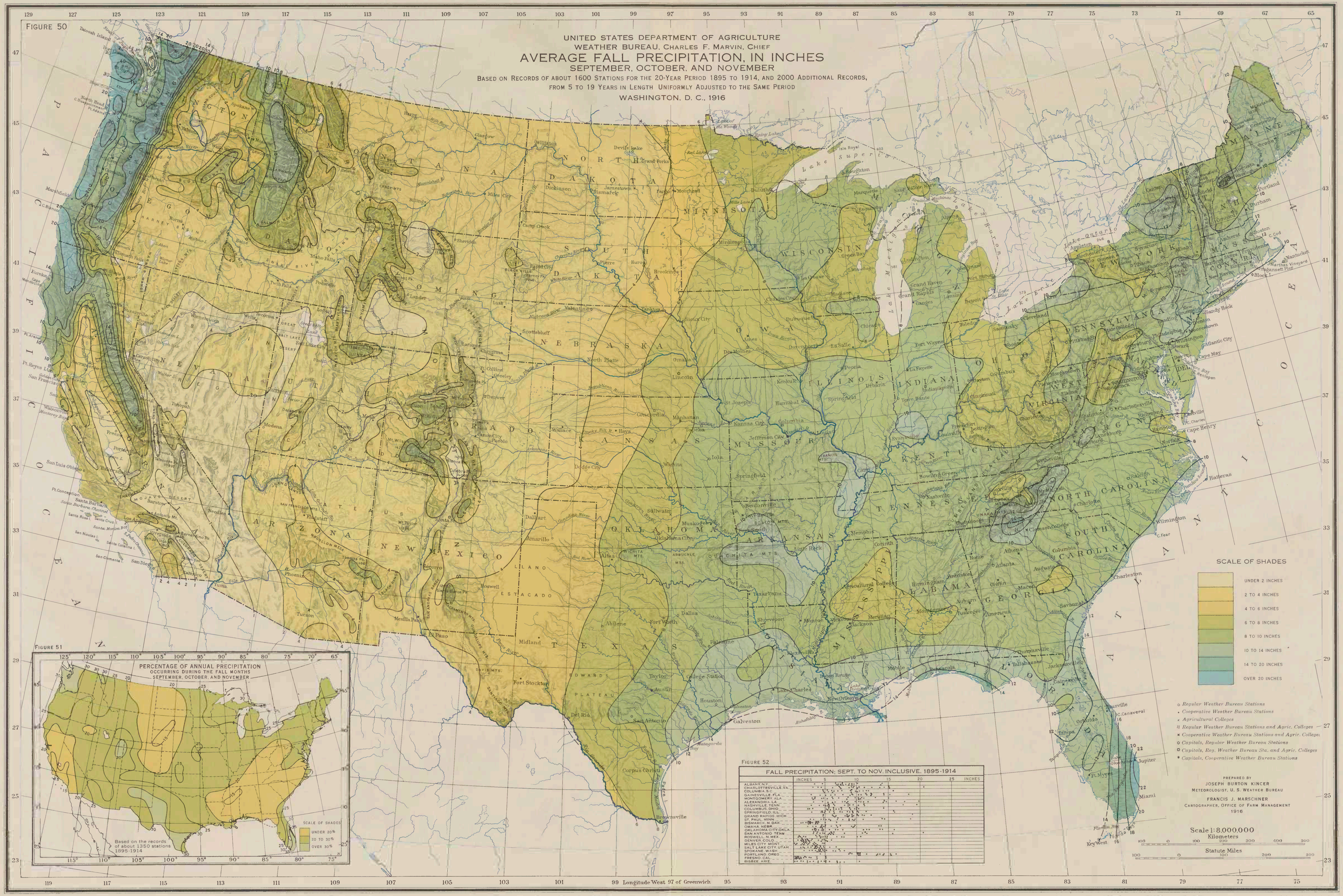


Figure 50.—This chart shows the average fall precipitation, September to November, inclusive. In the Pacific Coast States the rainy season sets in during the fall months and it is well established in the northern section by the end of November, when heavy snows usually begin at the higher altitudes. During November heavy snows often occur also in the mountains of Montana and Idaho. In the Great Plains region there is a rather rapid falling off in the amount of rainfall with the advent of autumn, and this condition is general also in most districts east of the Plains, but the diminution is not so marked. The heaviest precipitation during the fall season east of the Rocky Mountains occurs in the southeastern portion of the Florida Peninsula, where the totals for the three fall months at several stations are as much as 22 inches.

Figures 51 and 52.—The inset chart in the lower left-hand corner shows the percentage of the annual precipitation that occurs during the fall months. In most of the important agricultural districts of the country precipitation during the fall season is relatively light, usually ranging between 15 and 25 per cent of the annual amount. The graph at the bottom to the right shows for a number of representative stations, well distributed over the country, the total fall precipitation that occurred in each of the 20 years whose record was used in preparing the large chart. It indicates the characteristics of distribution and variations from year to year in different localities.

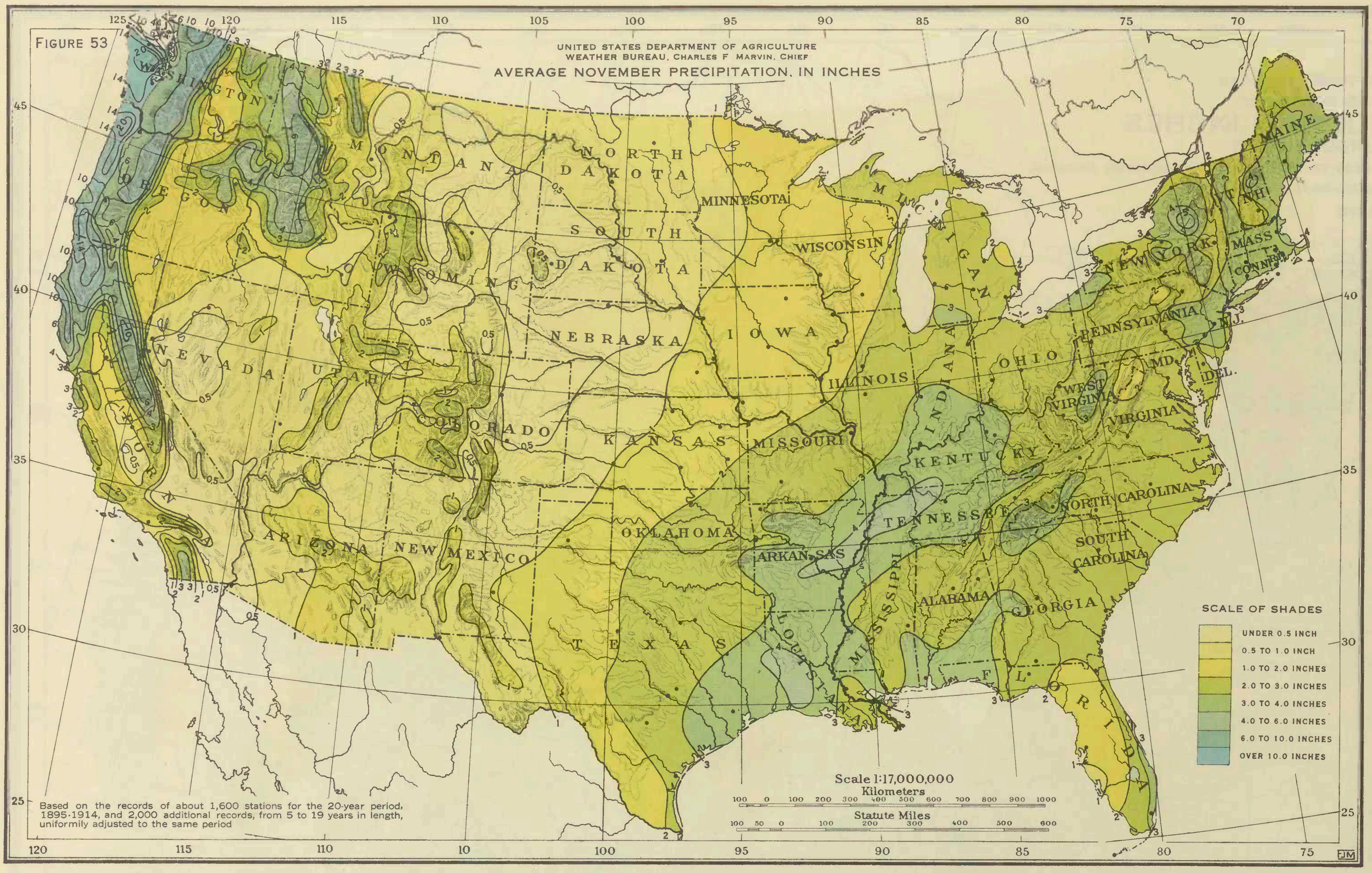
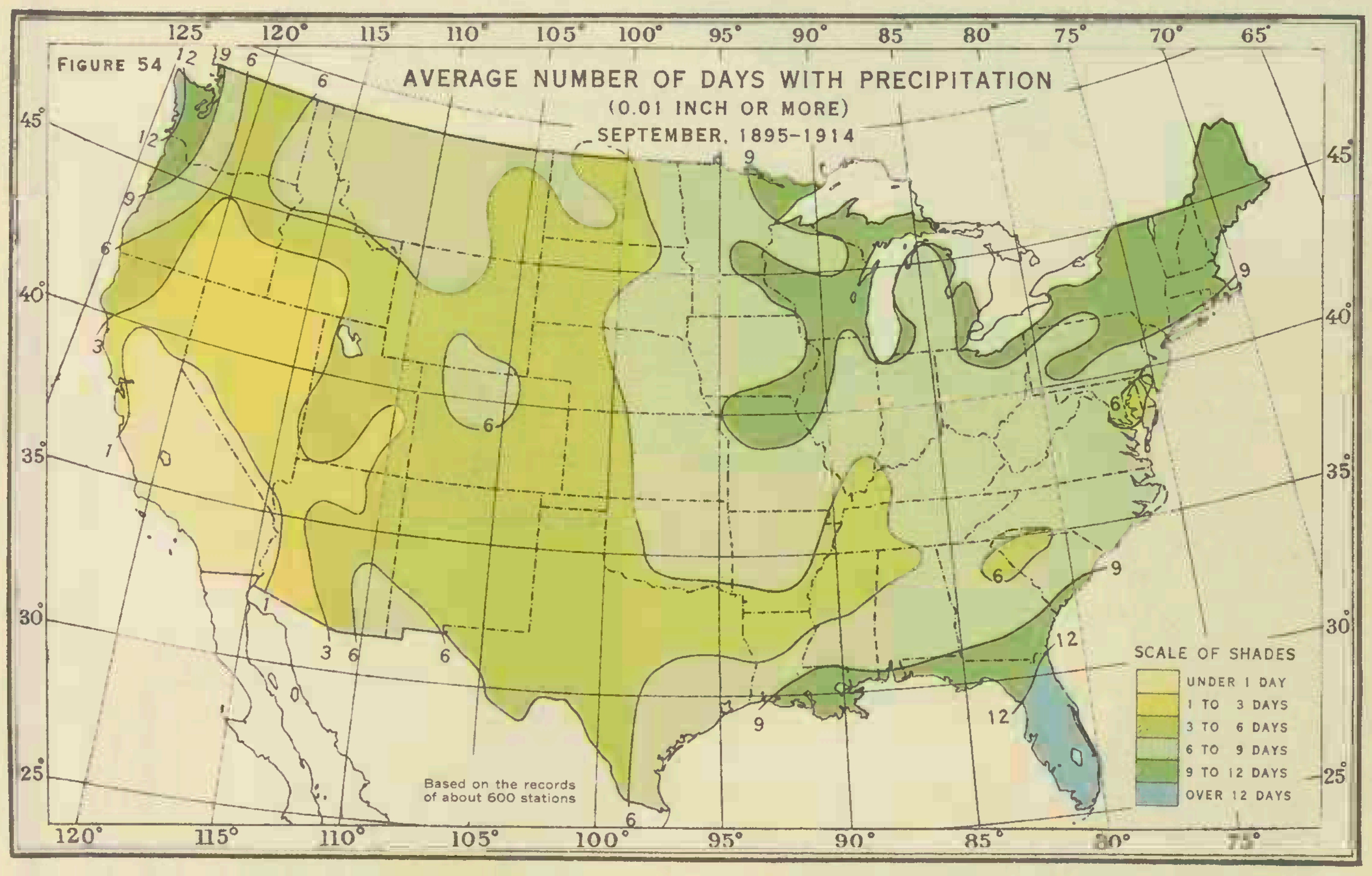
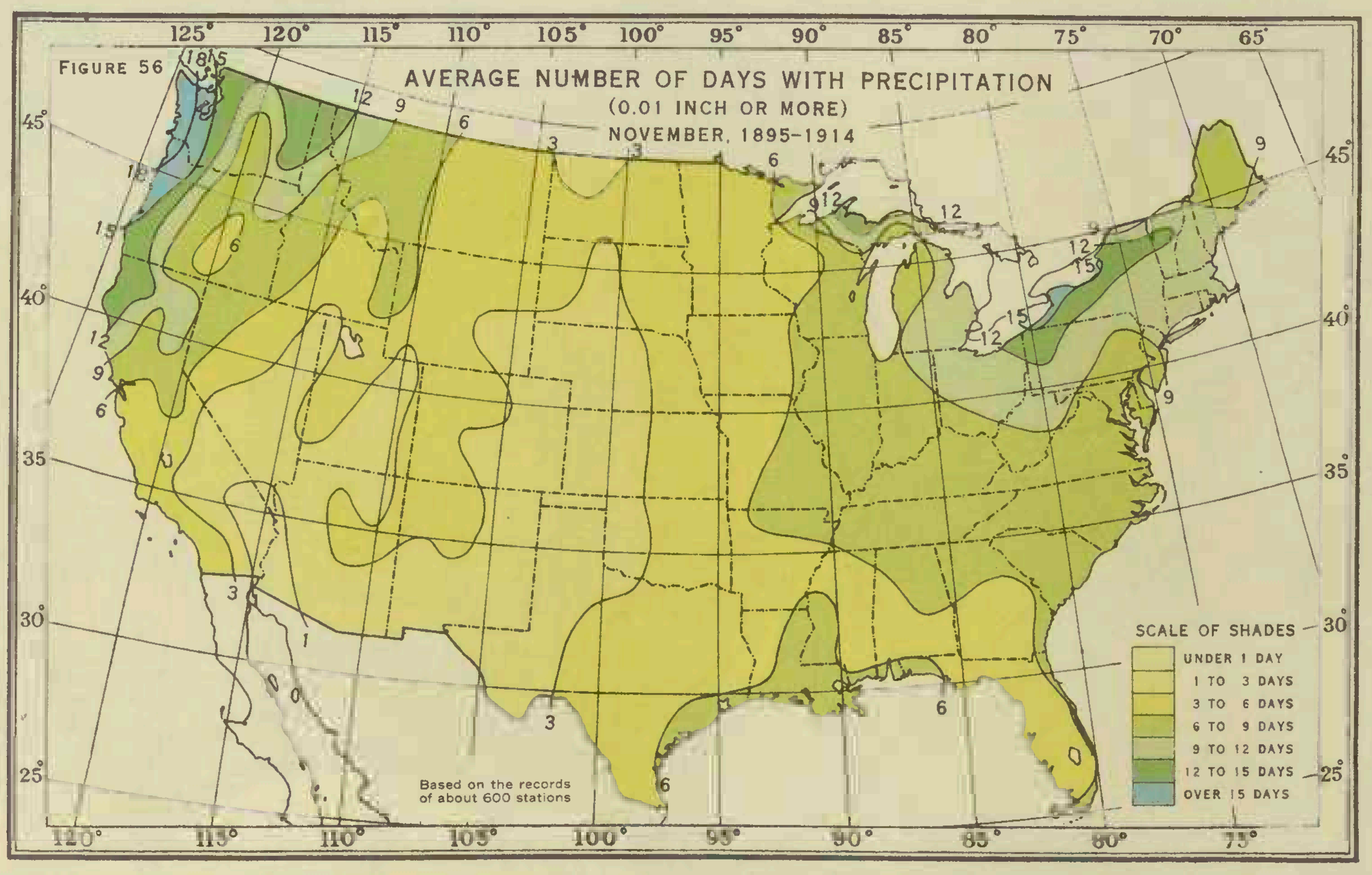
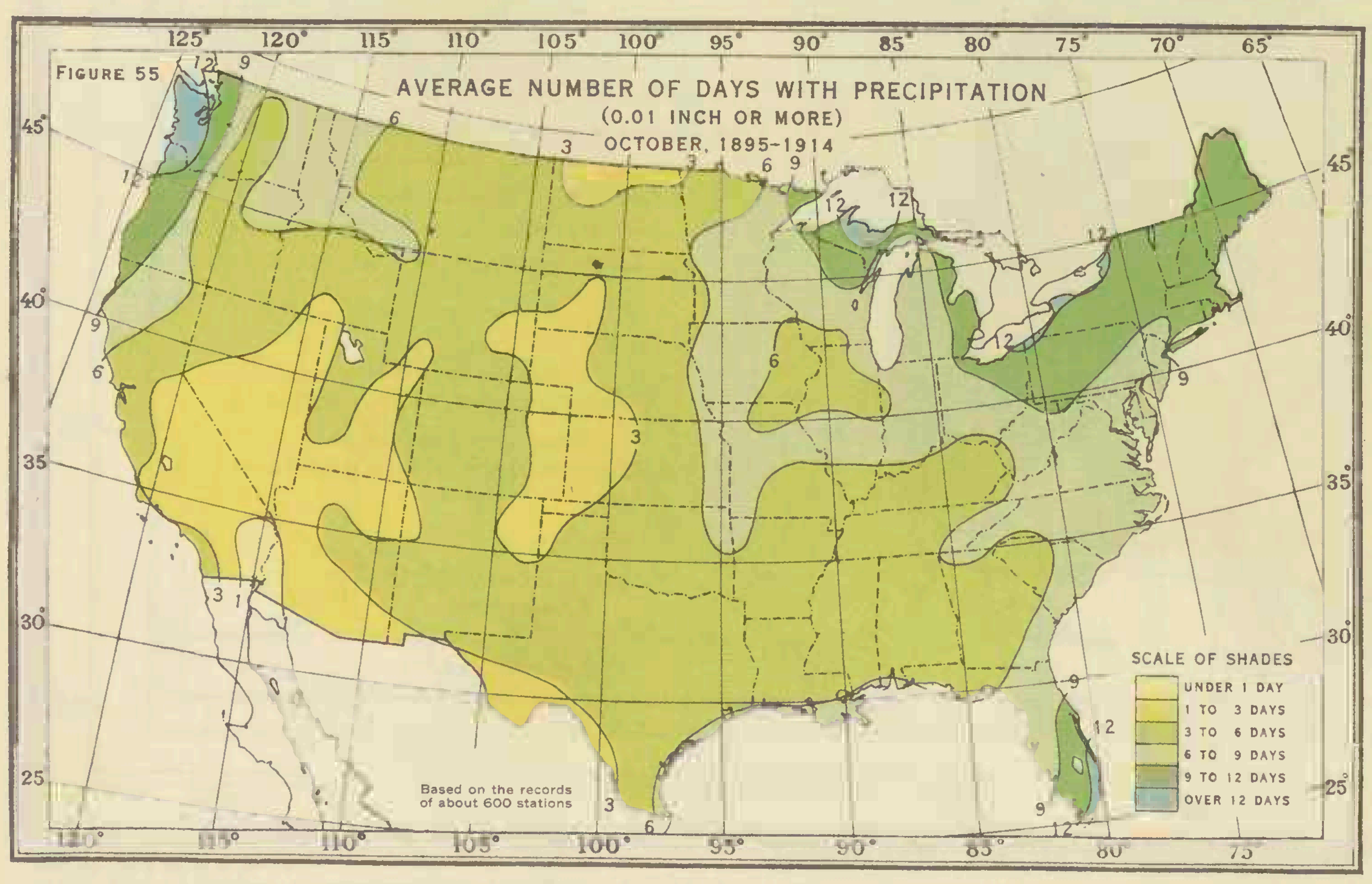
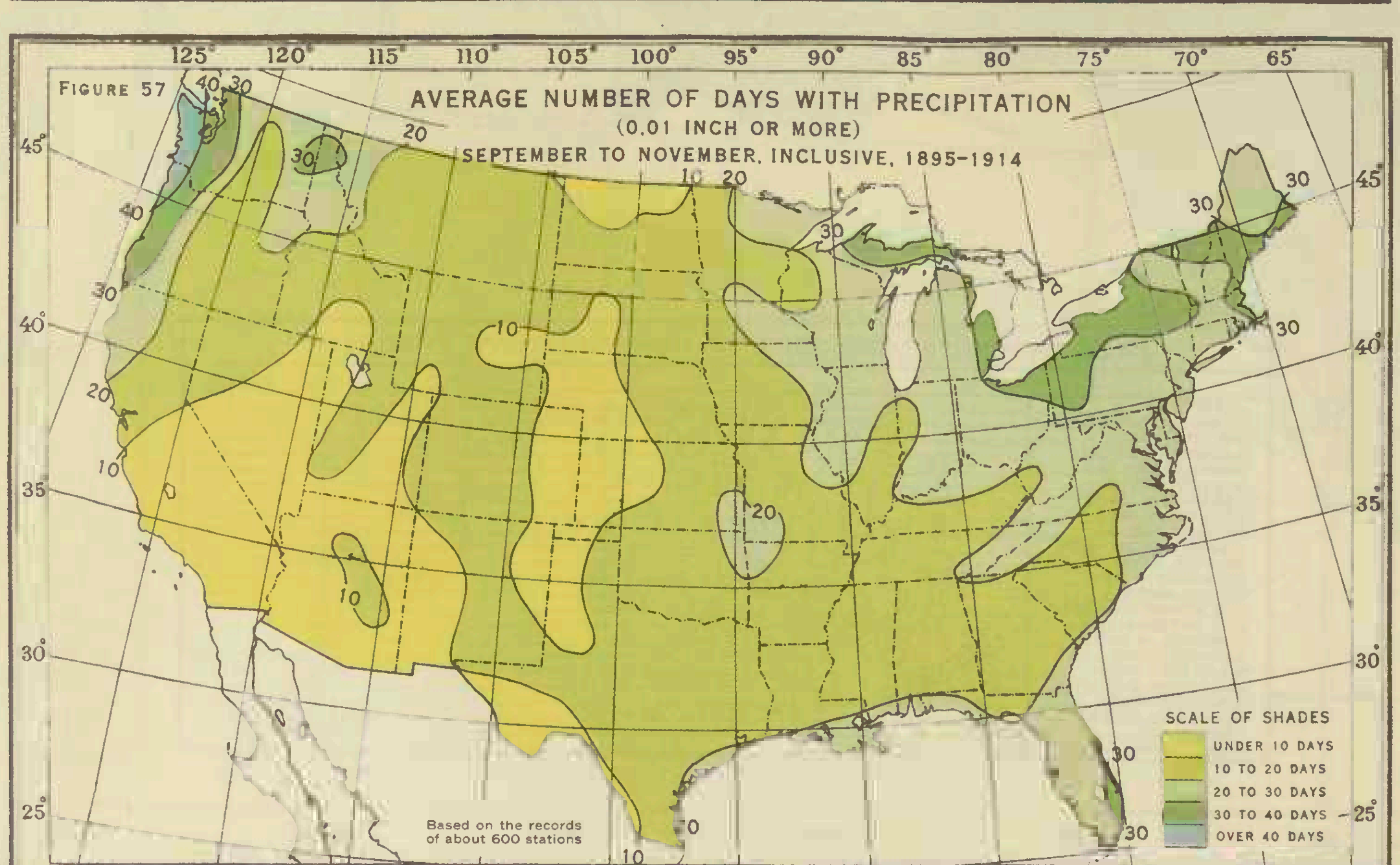


Figure 53.—In November thunderstorms are of much less frequent occurrence and the larger, or cyclonic, atmospheric disturbances are more active and become the principal source of precipitation. East of the Rocky Mountains the heaviest rainfall in this month usually occurs in the central and lower portions of the Mississippi Valley, where, at some places, the November rainfall averages slightly more than 4 inches; but from this region the average precipitation decreases in all directions. The decrease is especially marked to the westward and northwestward, the rainfall for the month in the Dakotas, Nebraska, and the central and western portion of Kansas being less than 1 inch. In the southeastern portion of the Florida Peninsula there is a remarkable decrease from averages of 8 to 10 inches in October to those of 2 to 3 inches in November. On the Pacific Coast the rainy season becomes more pronounced in November, the average rainfall for the month ranging from about 1 inch on the southern coast of California to from 14 to 20 inches on the coasts of Washington and Oregon. November is frequently the month of maximum precipitation along the North Pacific Coast.









Figures 54, 55, and 56 show the average number of days with precipitation for the months of September, October, and November, respectively, and Figure 57 shows the total number for the fall season. With the advent of fall, precipitation, as a rule, becomes of more frequent occurrence in the Pacific Coast States and less frequent east of the Rocky Mountains. By November the rainy season is well established along the Central and North Pacific Coast, precipitation occurring in the western portion of Washington and Oregon on about 18 days during this month, and along the northern California coast on from 10 to 15 days. East of the Mississippi River rain occurs, as a rule, with less frequency during the fall months than during any of the other seasons, the average number of days with rain during the three months in many of the important agricultural sections being less than 20.

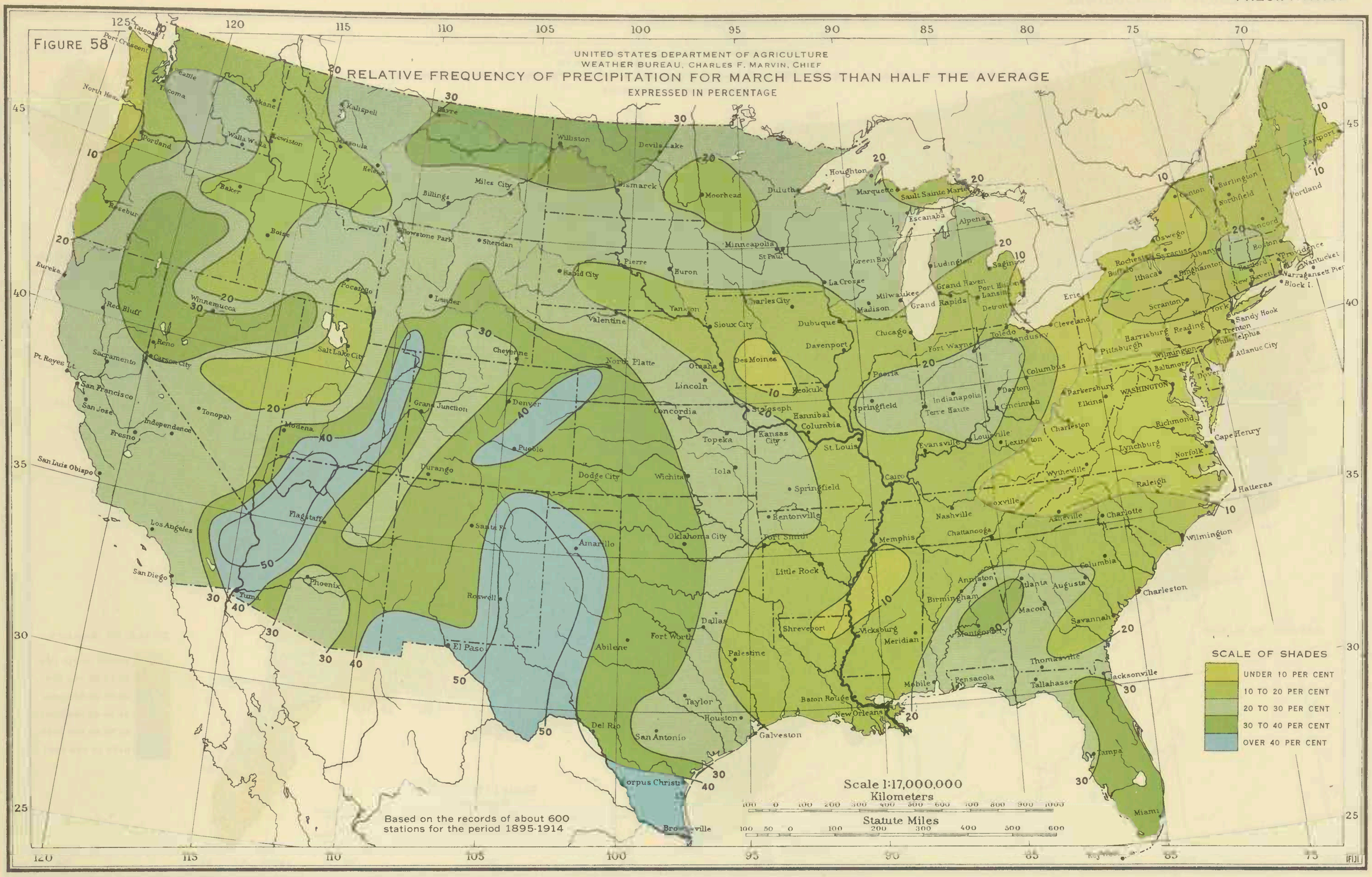


Figure 58.—Deficiencies of considerable amount from the average precipitation during the warm season of the year are of special agricultural significance. This and the succeeding seven charts show for each month from March to October the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation was less than half the average for the respective months. The localities having the least frequent occurrences of deficient precipitation of this amount for the month of March are found in the Middle Atlantic and portions of adjoining States, and also in the lower Mississippi Valley and along the North Pacific Coast, where in only 1 or 2 years of the 20 was the precipitation during March less than half the monthly average. The largest percentages for this month appear in Arizona, New Mexico, and the western portion of Texas, where over considerable areas the precipitation was less than 50 per cent of the average in half the years or more.

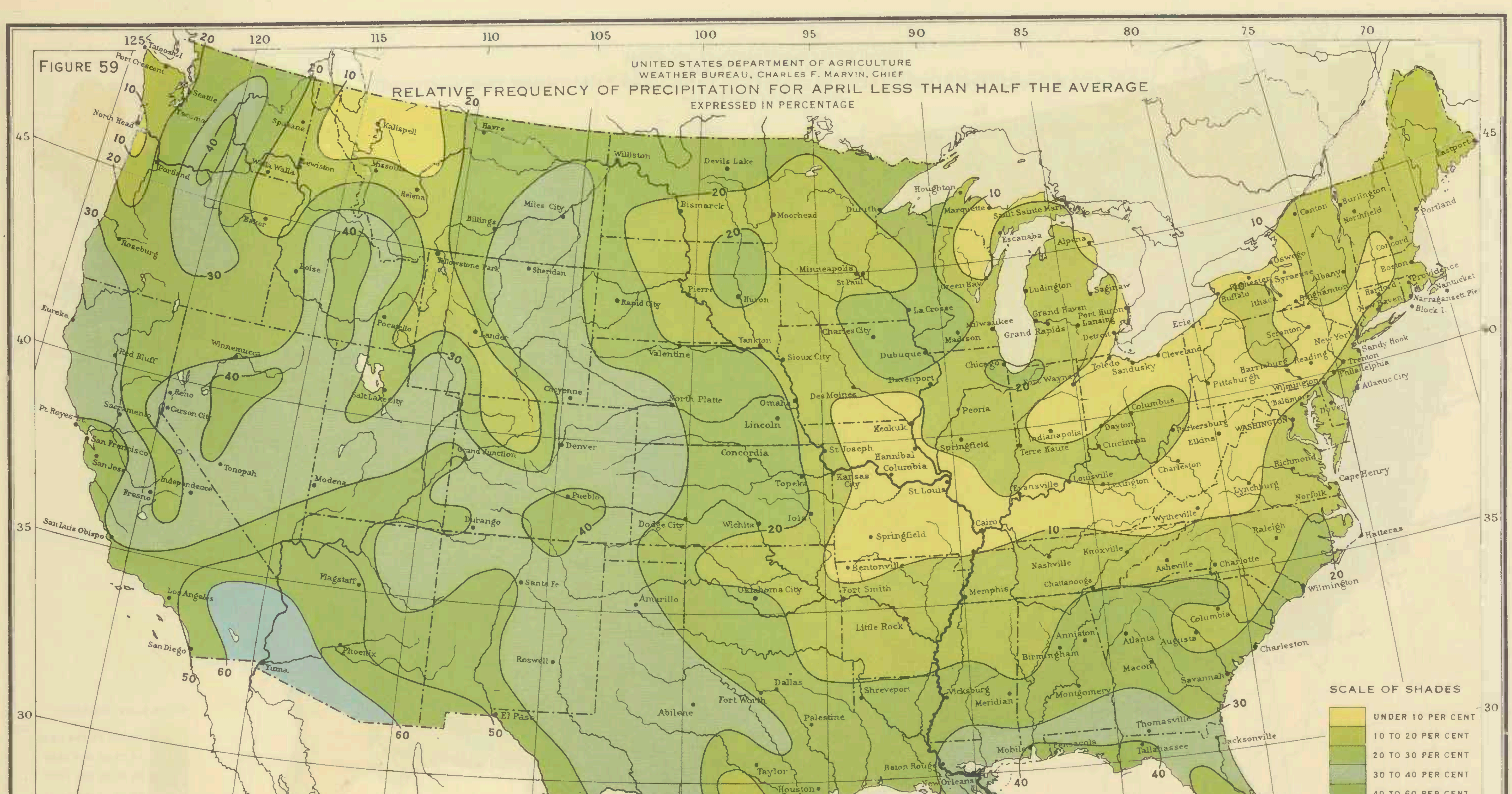


Figure 59.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation for the month of April was less than half the average. In the lower Missouri and middle Mississippi valleys, in Kentucky, and from the Virginias and Ohio northeastward deficiencies of this amount were, as a rule, infrequent for April during this period, only 1 to 2 years in the 20 having for this month less than 50 per cent of the average precipitation. On the other hand, in the regions lying just east of the Rocky Mountains, and also in portions of the eastern Gulf States, the percentages are large, there having been in those localities as many as 6 to 8 years of the 20 with deficiencies of this amount in the April precipitation. West of the Rocky Mountains the percentages are large, as a rule, the largest values appearing in the far Southwest, where at some places in more than half the years the precipitation for April was less than half the average.

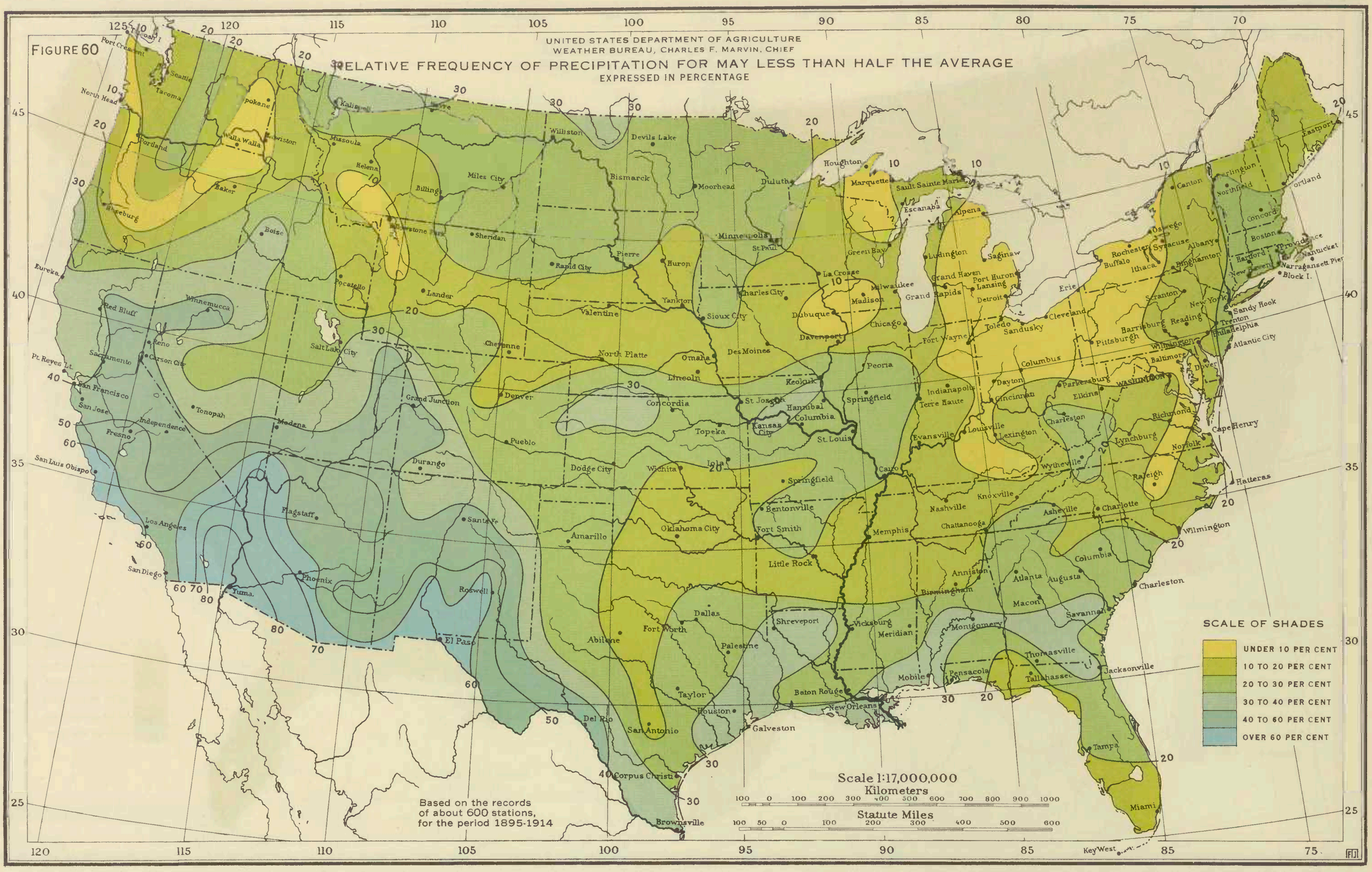


Figure 60.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation for the month of May was less than half the average. In general, the districts that had fewer such deficiencies for this month during the 20-year period are found in the States bordering on the Great Lakes, where in some localities only 1 year in the 20 had for May less than half the monthly average. Other areas of comparatively small percentages appear in the Middle Atlantic States and in parts of the Plains region. In portions of the lower Missouri Valley, where for April the percentages were as low as 5 to 10, May had deficiencies of this amount in 25 to 30 per cent of the years. The largest percentages appear in the far Southwest, where at some places as many as 16 years of the 20 had for this month less than half the average monthly rainfall. This is due to the fact that rainfall in those districts is usually very light, and occasional heavy rains unduly magnify the averages.

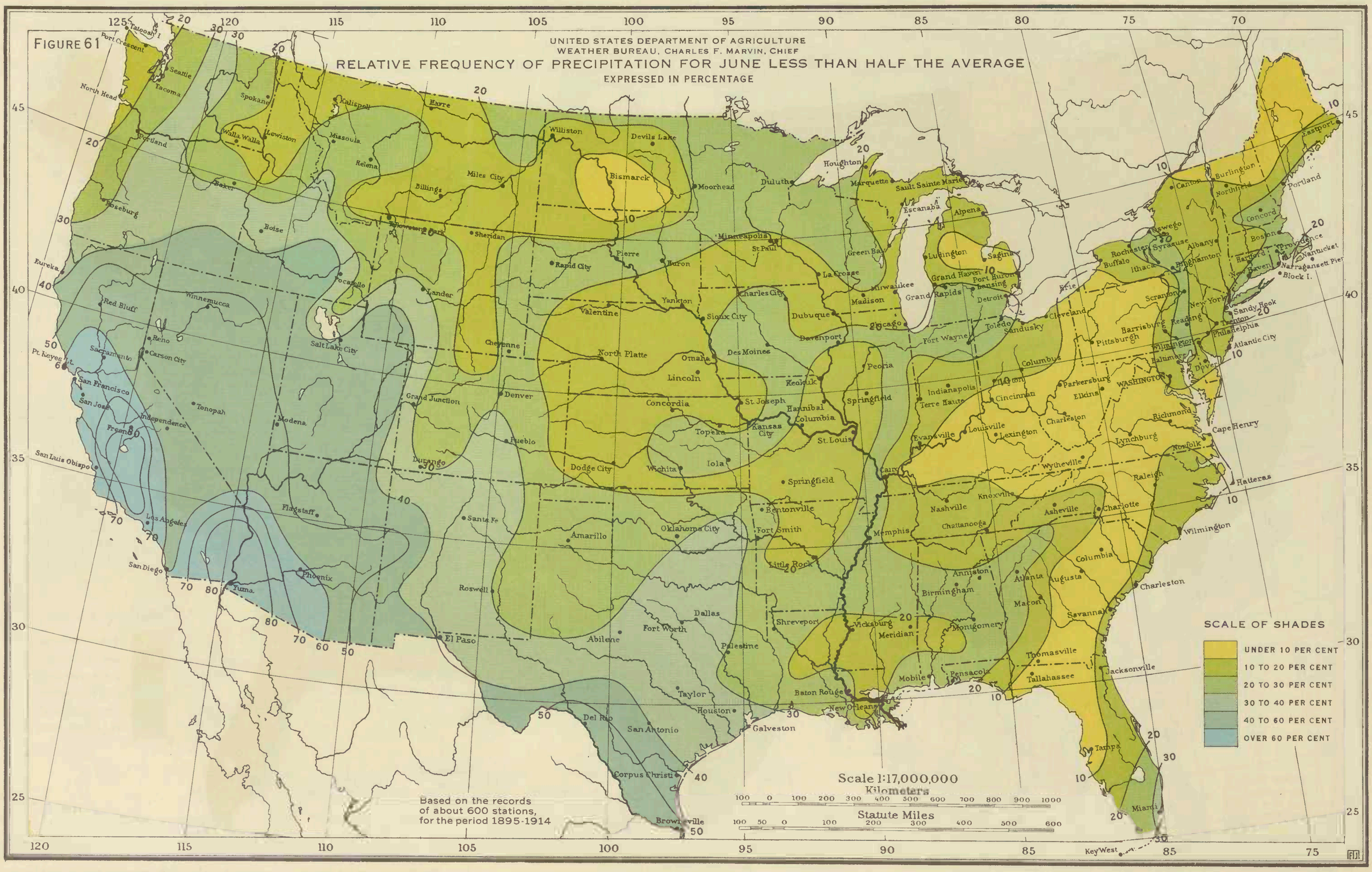


Figure 61.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation for the month of June was less than half the average. The areas of least frequent occurrence of deficiencies in precipitation of this amount for June are found in the Middle and South Atlantic States, the Ohio Valley and portions of the Great Lakes region, and also in portions of the spring-wheat belt, where, as a rule, only 1 or 2 years in the 20 had for this month less than half the average rainfall. In Texas, Arizona, and California, and generally to the westward of the Rocky Mountains the percentages are large, except along the North Pacific Coast and in the upper Columbia and Snake River valleys.

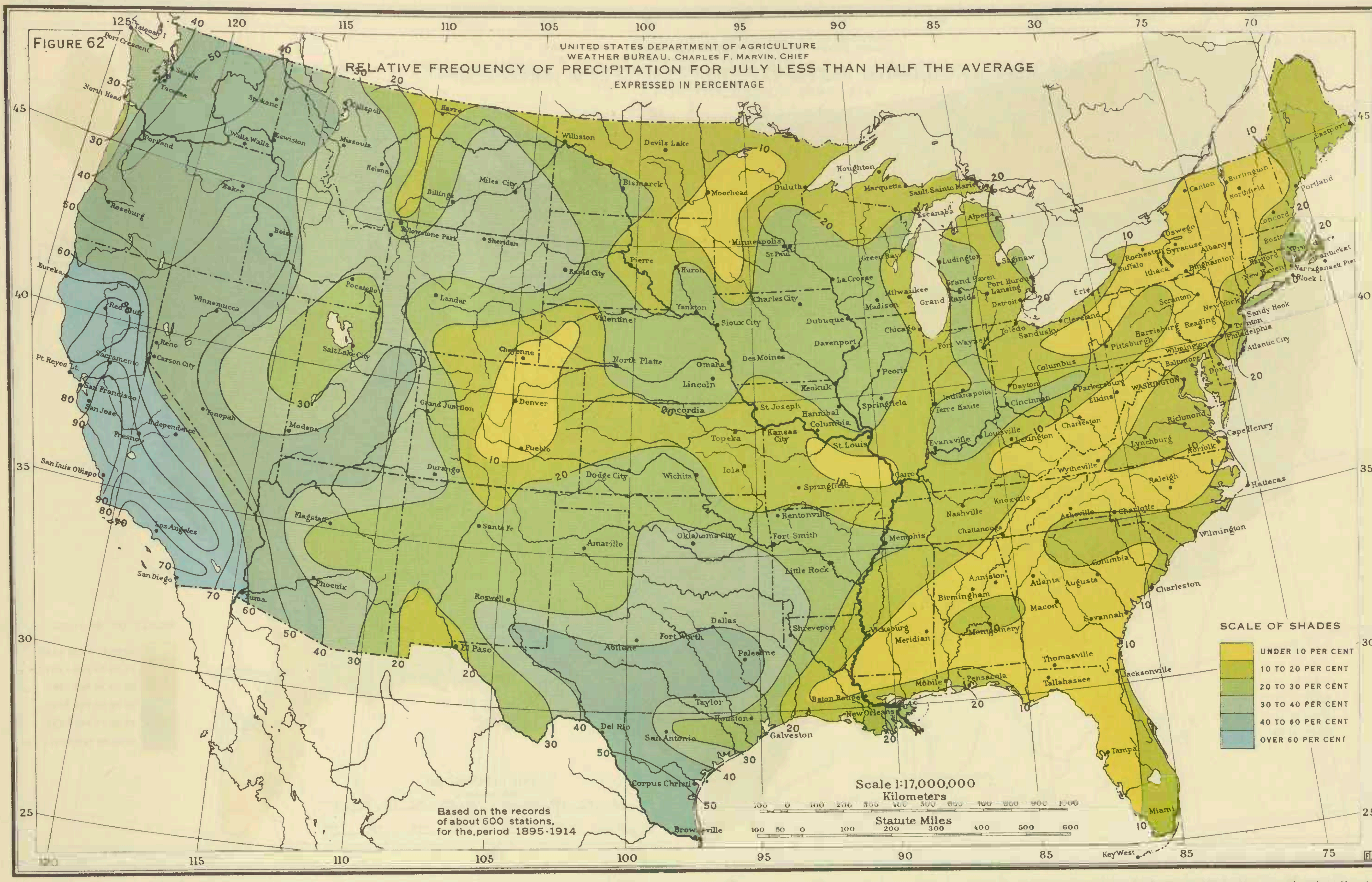


Figure 62.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation for the month of July was less than half the average. In the districts east of the Mississippi River July, as a rule, had few deficiencies of this amount, particularly in the central and eastern portions of the Cotton Belt, where in a number of localities only one such deficiency is recorded for the entire 20-year period, and at some points in no year was the July rainfall less than half the average. The largest percentages east of the Rocky Mountains appear in Texas, where in most places the July rainfall was less than half the average in about 8 of the 20 years. The percentages are large in the Pacific Coast States, particularly in California, but in Arizona and New Mexico they are much smaller than for June, due to the fact that in these States the rainy season is on and the average is not affected so greatly by occasional heavy rains as it is in other seasons of the year.

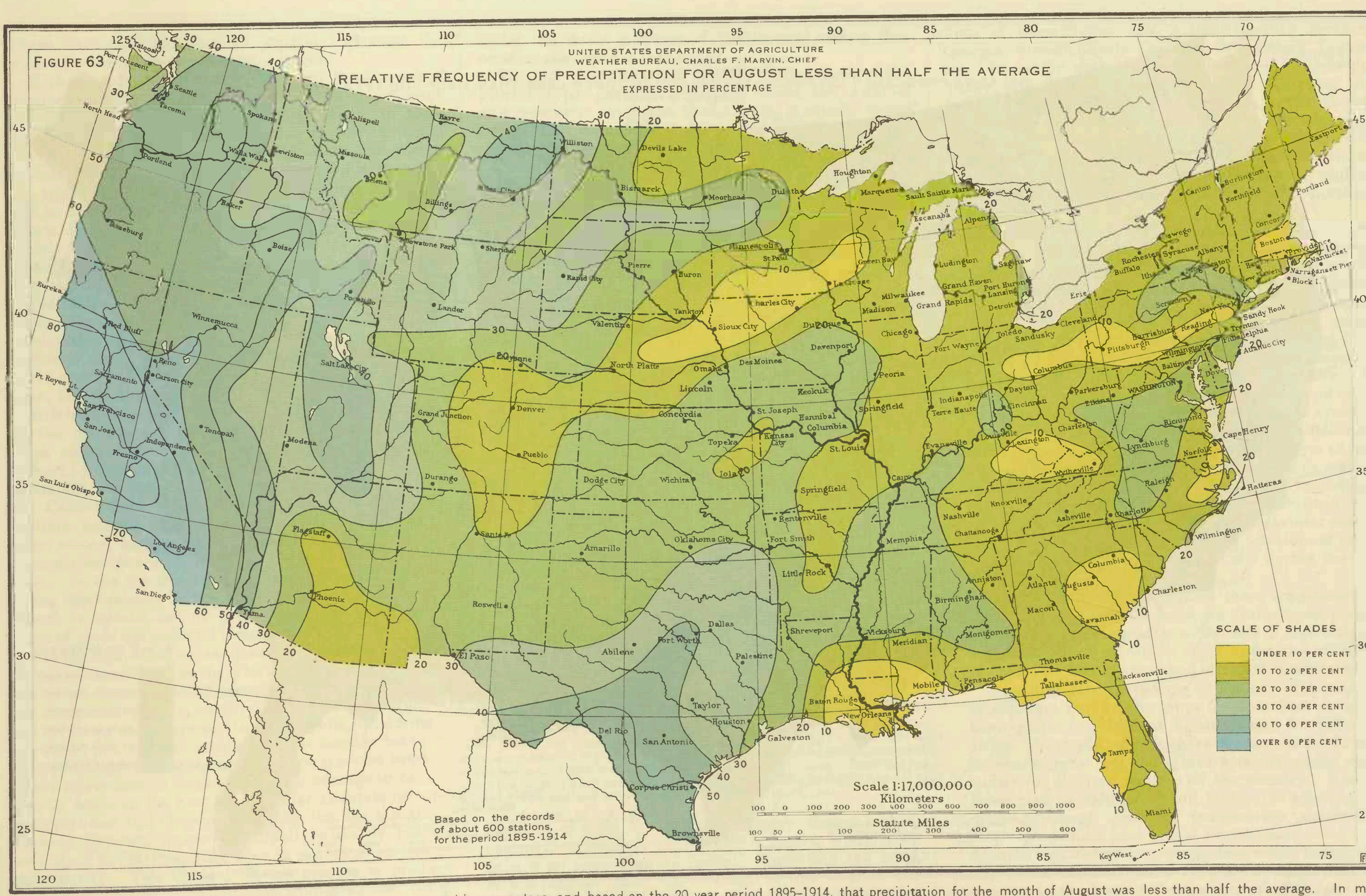


Figure 63.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895–1914, that precipitation for the month of August was less than half the average. In most districts east of the Mississippi River fewer than 4 years of the 20 had during August less than half the average precipitation for this month. Other districts showing small percentages for August are found in north-central Arkansas, eastern Missouri, portions of the upper Mississippi and middle Missouri valleys, the central Rocky Mountain region, and in Arizona, the last named being due to the continuation of the rainy season in that region. Except in Arizona, the percentages in the districts west of the Rocky Mountains are large, less than half the average rainfall for the month occurring generally in from 8 to 16 years of the 20. In most of Texas deficiencies of this amount occurred in August in more than one-third of the years.

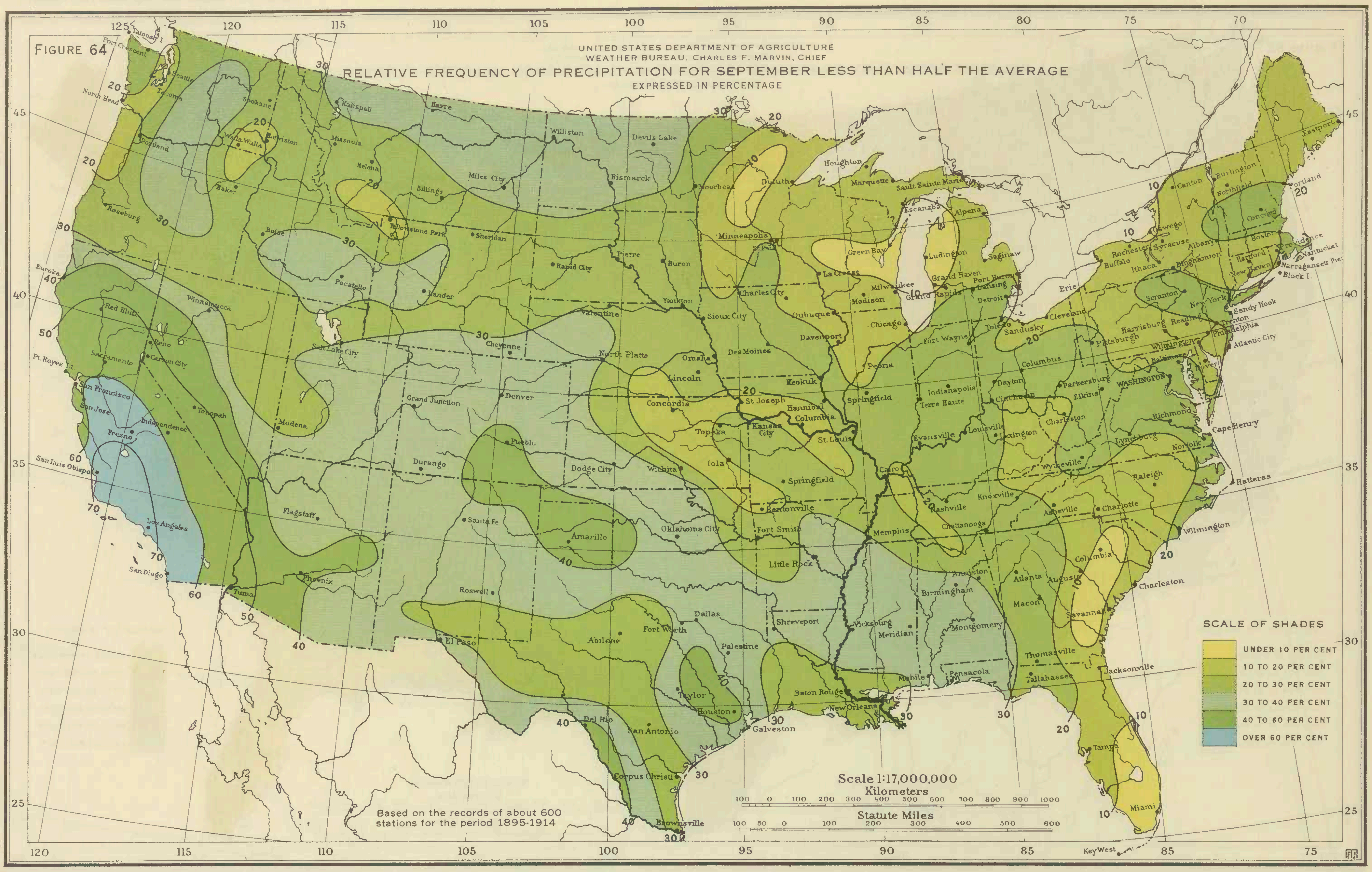


Figure 64.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period, 1895-1914 that precipitation for the month of September was less than half the average. East of the Mississippi River, except in portions of the Lake region and of South Atlantic States, deficiencies of this amount were of more frequent occurrence during September than during the preceding months of the warm season, many localities having as many as 5 years of the 20 with less than half the average monthly rainfall. West of the Mississippi River the smallest percentages for this month are found in eastern Kansas and central Missouri, where only 3 or 4 years of the 20 had rainfall in September, less than half the monthly average. In Texas and most districts west of the Rocky Mountains the September percentages are appreciably less than those for August, but in Arizona they are markedly greater, due to the cessation of the rainy season in that State.

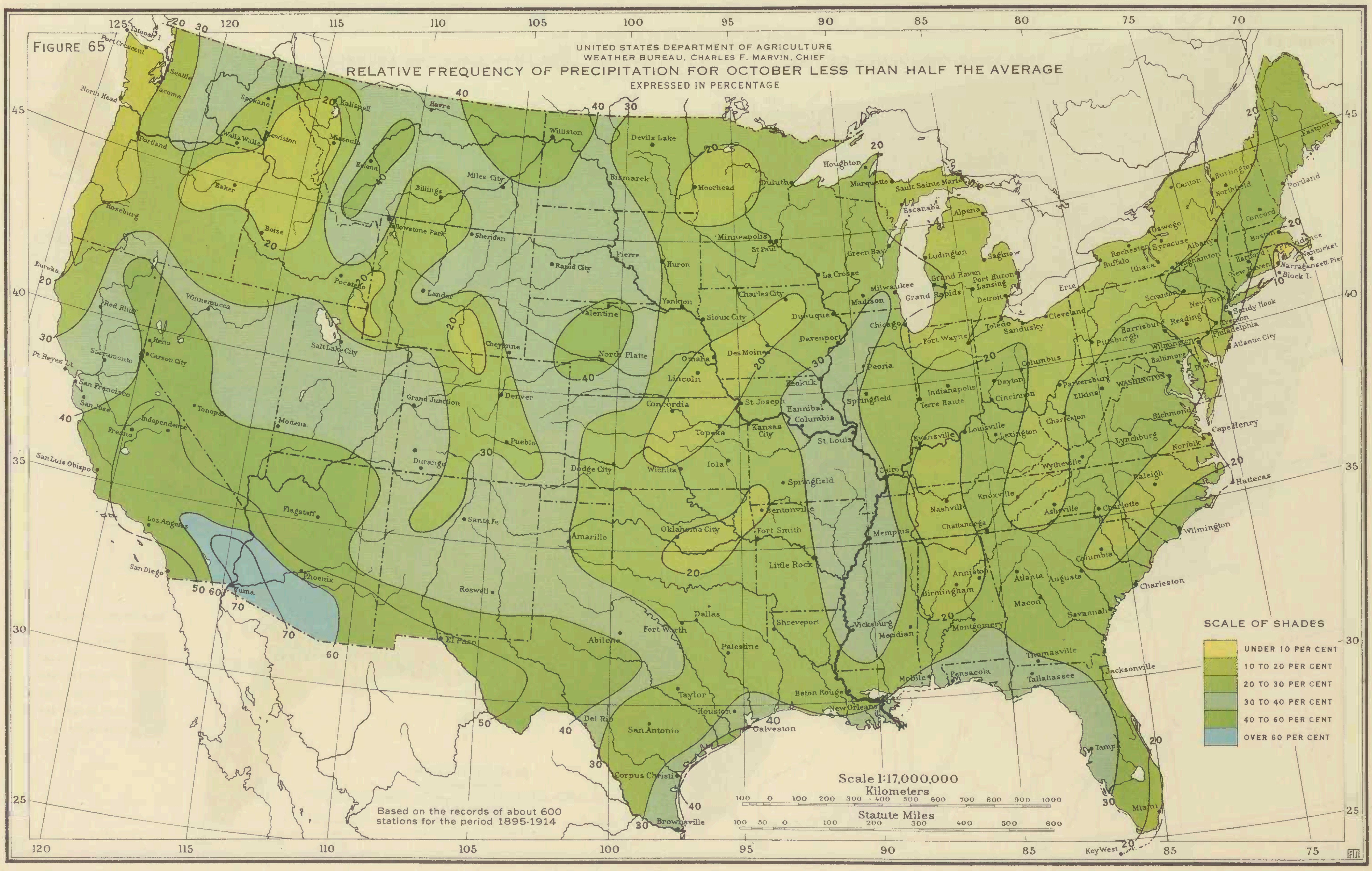


Figure 65.—This chart shows the relative frequency, expressed in percentage, and based on the 20-year period 1895-1914, that precipitation for the month of October was less than half the average. Along the Mississippi River and eastward the October percentages are rather large as compared with the other months included in this series of percentage charts, but in most of Texas and over the eastern portions of the Plains States they are comparatively small. Other areas of rather small percentages for this month are found along the North Pacific Coast and in the northern Interior Plateau region. The largest percentages appear in the far Southwest, particularly in the extreme southeastern portion of California and southwestern Arizona, where in 14 years of the 20 precipitation for October was less than half the average monthly amount. Comparatively large percentages appear also in Montana and the western portions of the Dakotas and Nebraska.

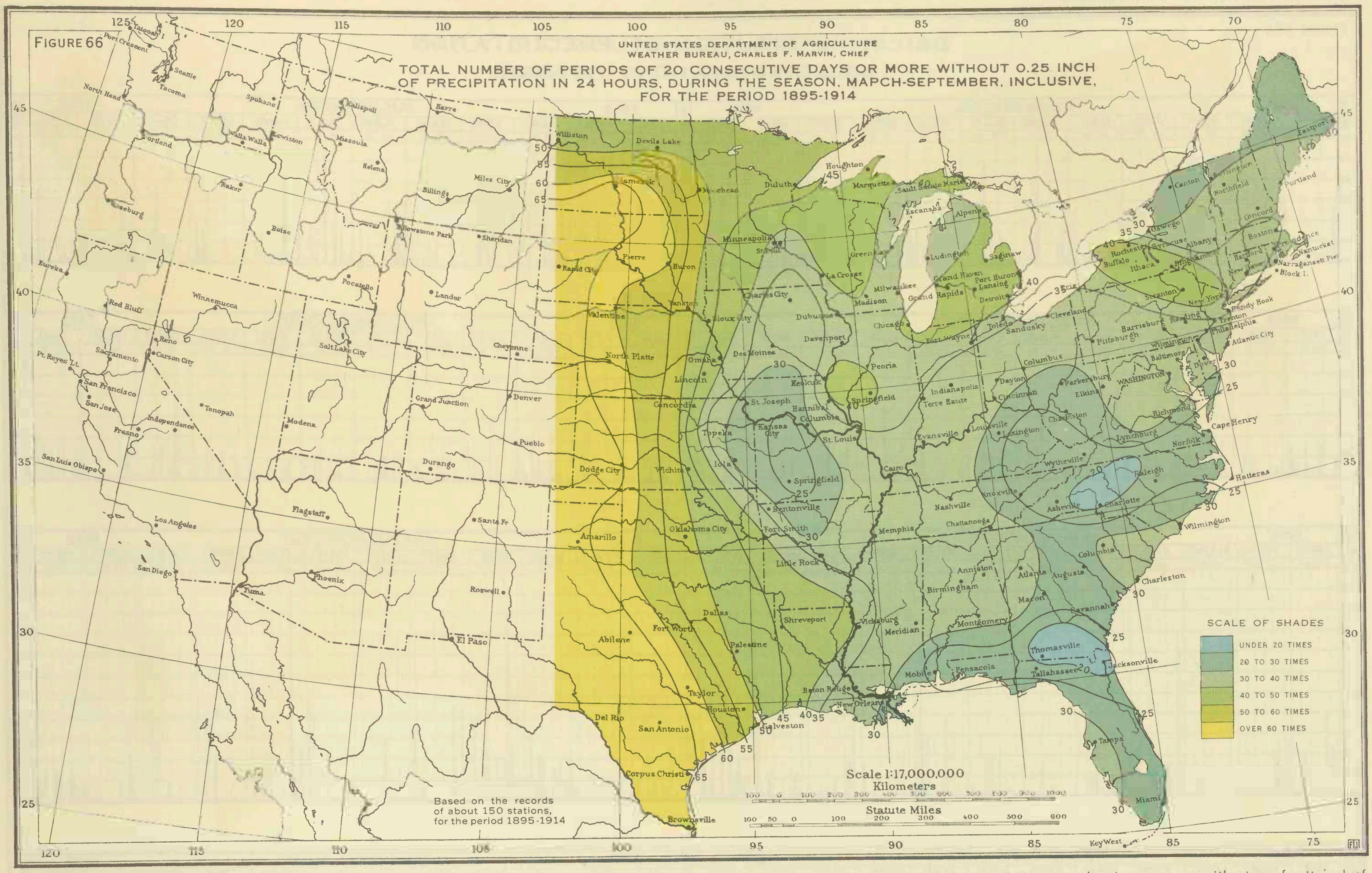


Figure 66.—This chart shows, for the season from March 1 to September 30, for districts from the Great Plains eastward, the total number of periods of 20 consecutive days, or more, without one-fourth inch of precipitation in 24 hours during the 20-year period 1895-1914. The chart is based on the records of all regular reporting stations within the districts mentioned having full 20-year records, about 150 in number. The areas having the fewest such periods of deficient precipitation are found in the Middle and South Atlantic States and in the lower Missouri Valley, where such droughts occurred on the average about once in a season. The most frequent occurrences are found in the western portions of the Plains States, where the average is about three in each season.

Texas northeastward through central Minnesota the winter precipitation is less than 2 inches.

With the advance of spring, however, the amount of precipitation in this region increases rapidly, although the increase is not pronounced until May. In Montana and the Dakotas, May and June are the months of heaviest rainfall, the amount being somewhat greater in June, while for the other States included in this type the rainfall in May, June, and July is about equal. It will be noted by reference to the monthly precipitation charts, figures 33, 38, and 39, that a large area immediately to the westward of the Mississippi River, including a half dozen or more States, either wholly or in part, receives on the average more than 4 inches of rainfall during each of the months of May, June, and July. The seasonal distribution of precipitation in percentages of the annual for much of the Plains region is about as follows: Winter, less than 10 per cent; spring, 25 to 30 per cent; summer, 40 to 50 per cent; fall, 15 to 20 per cent.

Eastern type.—This type, broadly speaking, includes all the country east of that covered by the Plains type, except the Florida Peninsula, and is characterized by comparatively uniform distribution of precipitation throughout the year, especially north of the Cotton Belt. However, the rainfall during the autumn months is, in general, lighter than for any other season, particularly in most of the Cotton Belt, a condition favorable for the gathering of the cotton crop. In the Southern States there are some interesting fluctuations in the amounts of rainfall from month to month, but no pronounced seasonal variations of great agricultural importance are shown.

Florida type.—Important seasonal variations in precipitation are found in the Florida Peninsula. Here the seven months from November to May, inclusive, are comparatively dry, only from 2 to 3 inches of rainfall occurring on the average in each month, but during the other five months precipitation is usually heavy, July and August being especially wet on the west coast, where more than 10 inches fall on the average in each month, while on the east coast similar amounts occur in September and October. During the five months June to October, inclusive, rainfall is usually heavier over the Florida Peninsula than in any other section of the country. Two distinct factors operate to produce this heavy rainfall, convectional thunderstorms being responsible for the large amount usually received along the west coast during July and August, while the heavy rainfall on the eastern side of the peninsula in September and October is due to the fact that this coast comes under the direct influence of the tropical storms that occasionally occur in that region.

The heavy late summer rainfall, characteristic of the Florida type, extends northward along the Atlantic and westward along the Gulf Coasts, gradually merging in each direction into the more uniform seasonal distribution of the Eastern type of precipitation.

Area of maximum rainfall by months.—The area of maximum rainfall east of the Rocky Mountains for the several months of the year usually shows average amounts of from 5 to somewhat more than 6 inches, except from June to September, inclusive, which have from 8 to more than 10 inches. Excluding the more or less isolated cases, the locations of this area for the several months are as follows: In January it occupies the lower Mississippi Valley; by February it is farther east and overlies the southern portions of Mississippi and Alabama; in March it includes the northern portions of those States, with extensions into northern Georgia, western North Carolina, and eastern Tennessee. In April it again appears in the lower Mississippi Valley, and in May it occupies western Arkansas and eastern Oklahoma. In June it appears in the Florida Peninsula, where it remains during the following four months. In November, the only time during the year with averages less than 5 inches it occupies the Mississippi Valley from western Tennessee southward, while in December it is restricted to a limited area in northern Mississippi.

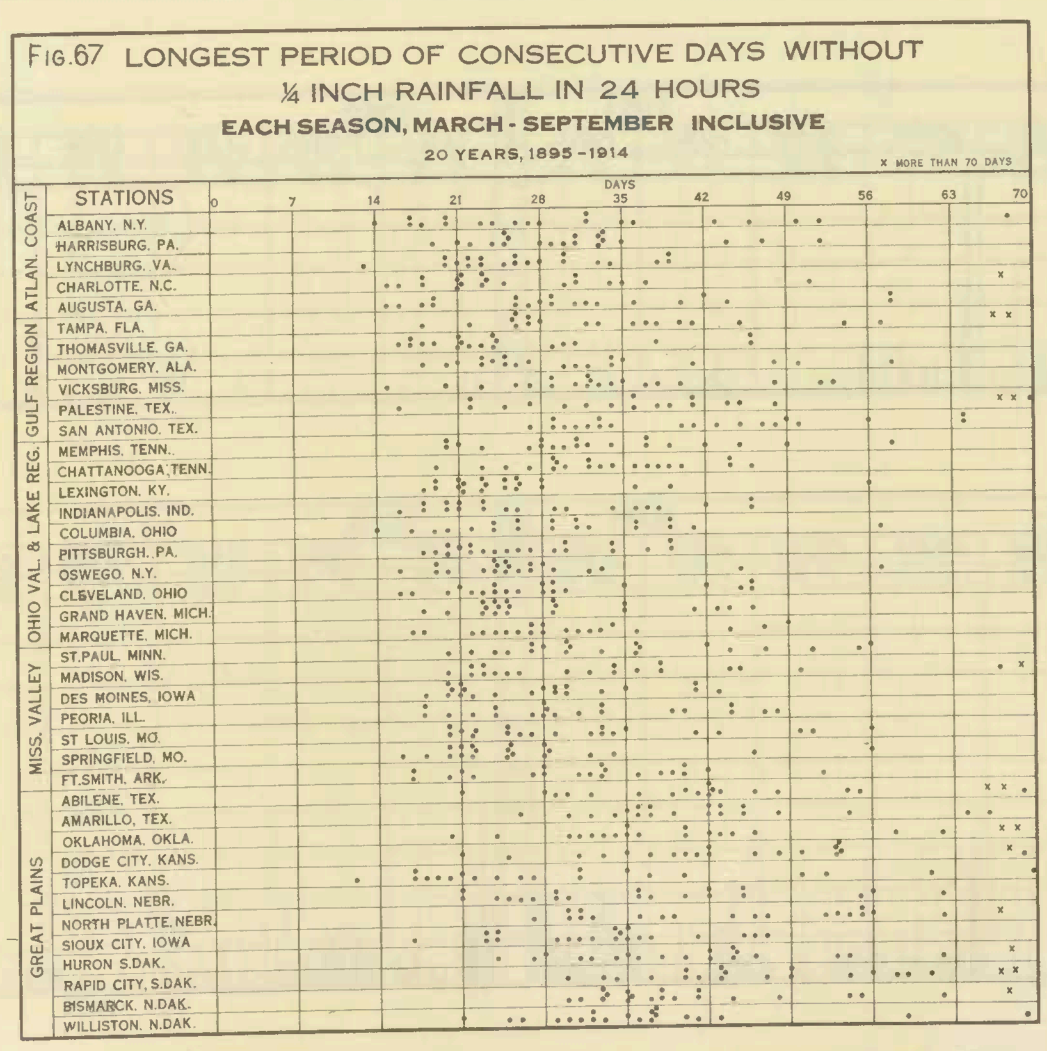


Figure 67.—This graph shows for selected stations east of the Rocky Mountains, during the 20 years 1895–1914, the longest period of consecutive days each warm season, March to September, inclusive, during which precipitation to the amount of one-fourth inch in 24 hours did not occur. Each dot represents the longest such period for a single season, there being 20 dots for each station. The stations are arranged by geographic divisions.

Rainfall of the crop-growing season.—Figure 8 shows for the different sections of the country the average amount of precipitation occurring during the warm season, April to September, inclusive, often designated the crop-growing season. In the eastern two-thirds of the United States it is the rainfall of this period with which the farmer is mostly concerned, but from the Rocky Mountains westward the amounts occurring in the winter months are of greatest importance. In fact, for some western localities the amount of snow stored in the mountains during the winter, as a reserve water supply for irrigation purposes in the following growing season, largely determines the degree of success for many farming operations. Again, in most of the Pacific Coast region fall-sown grains under the influence of comparatively mild temperatures and ample moisture conditions during the winter season grow steadily and mature after the cessation of rains, using the moisture stored in the soil during the wet winter months.

East of the Rocky Mountains these conditions are largely reversed. Here fall-sown grains make practically no advancement after winter sets in, but with the advent of spring growth is rapid under the influence of favorable temperature and moisture conditions.

Moisture Requirements of Crops.—The amount of moisture required by crops for their best development varies for different localities and for different crops. In studies of this character several modifying influences must be taken into account, which vary widely for different sections of the country. Among these may be mentioned soil texture as affecting its moisture-retaining qualities, temperature conditions, amount of sunshine, and rate of evaporation.

Rainfall required for crop production.—The amount of precipitation required under favorable distribution for the successful production of crops in much of the country east of the Rocky Mountains is considerably less than the average amounts shown in the annual precipitation chart. It is usually considered that between 15 and 20

FIGURE 68A

DAILY DISTRIBUTION OF PRECIPITATION
SELECTED STATIONS 1911-1912

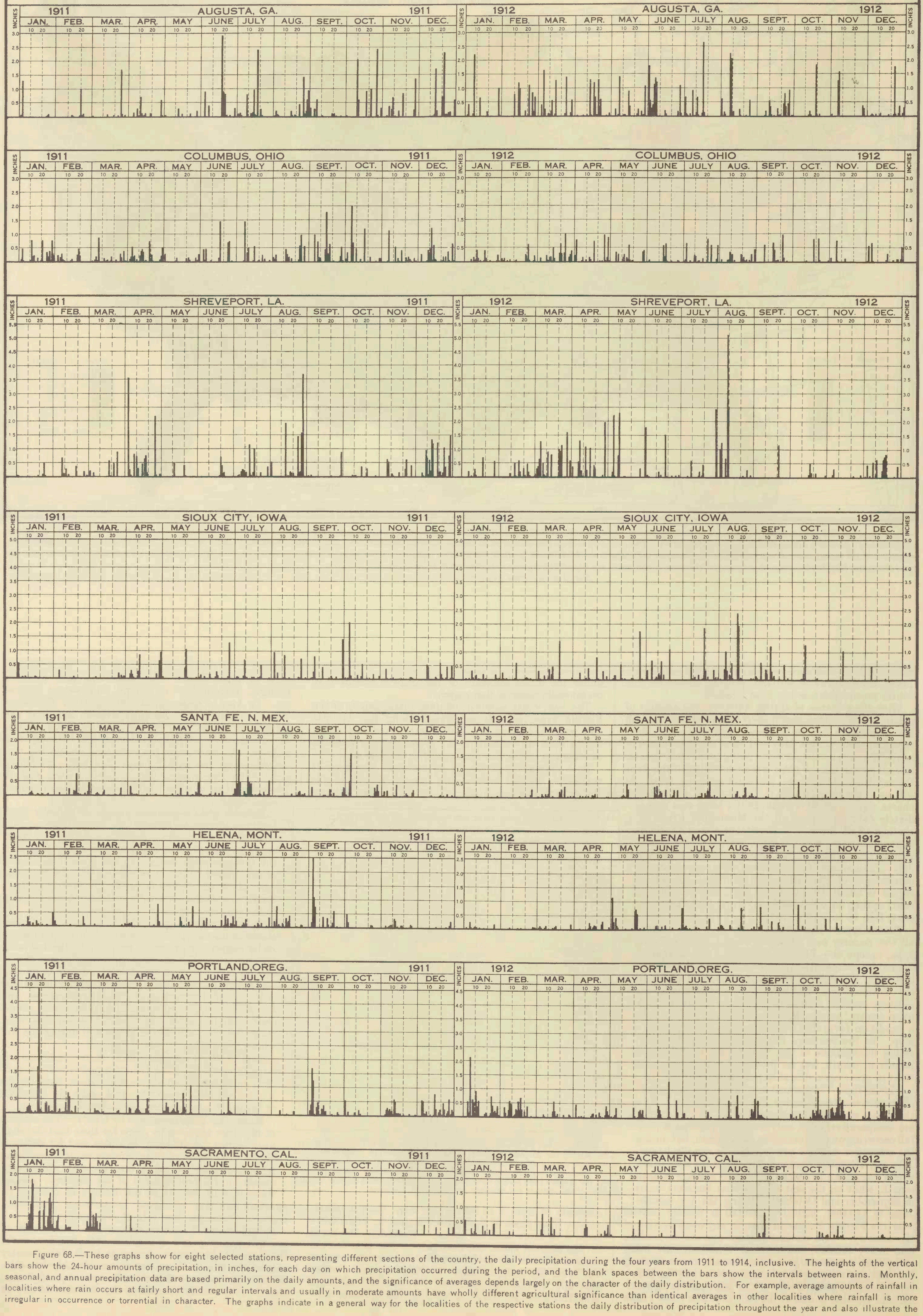
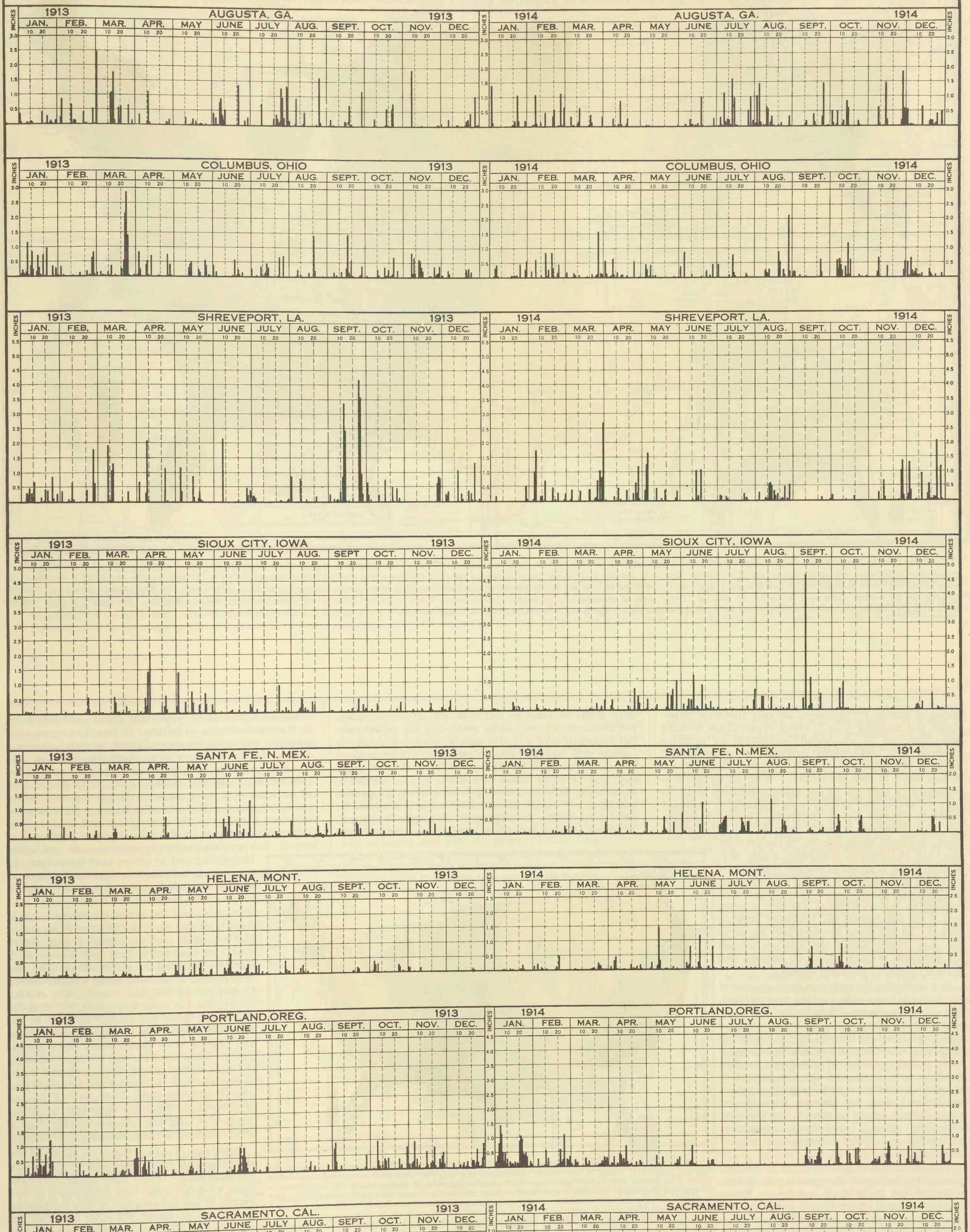


Figure 68.—These graphs show for eight selected stations, representing different sections of the country, the daily precipitation during the four years from 1911 to 1914, inclusive. The heights of the vertical bars show the 24-hour amounts of precipitation, in inches, for each day on which precipitation occurred during the period, and the blank spaces between the bars show the intervals between rains. Monthly, seasonal, and annual precipitation data are based primarily on the daily amounts, and the significance of averages depends largely on the character of the daily distribution. For example, average amounts of rainfall in localities where rain occurs at fairly short and regular intervals and usually in moderate amounts have wholly different agricultural significance than identical averages in other localities where rainfall is more irregular in occurrence or torrential in character. The graphs indicate in a general way for the localities of the respective stations the daily distribution of precipitation throughout the year and also illustrate the

FIGURE 68B

DAILY DISTRIBUTION OF PRECIPITATION
SELECTED STATIONS 1913-1914



irregular character of the intervals between rains. It will be noted from the graphs for Augusta, Ga., and Shreveport, La., that occasionally very heavy rainfall may be expected in the Southern States. These heavy rains are of little agricultural value, but they increase the monthly, seasonal, and annual averages to an extent that render these averages not strictly representative from an agricultural standpoint. In the Ohio Valley and in the Plains States, represented by Columbus, Ohio, and Sioux City, Iowa, respectively, heavy rains are not of so frequent occurrence and the intervals between rains are comparatively uniform. In California precipitation is irregular, as shown by the graph for Sacramento, but it is more uniform in western Washington and Oregon, as indicated by the graph for Portland.

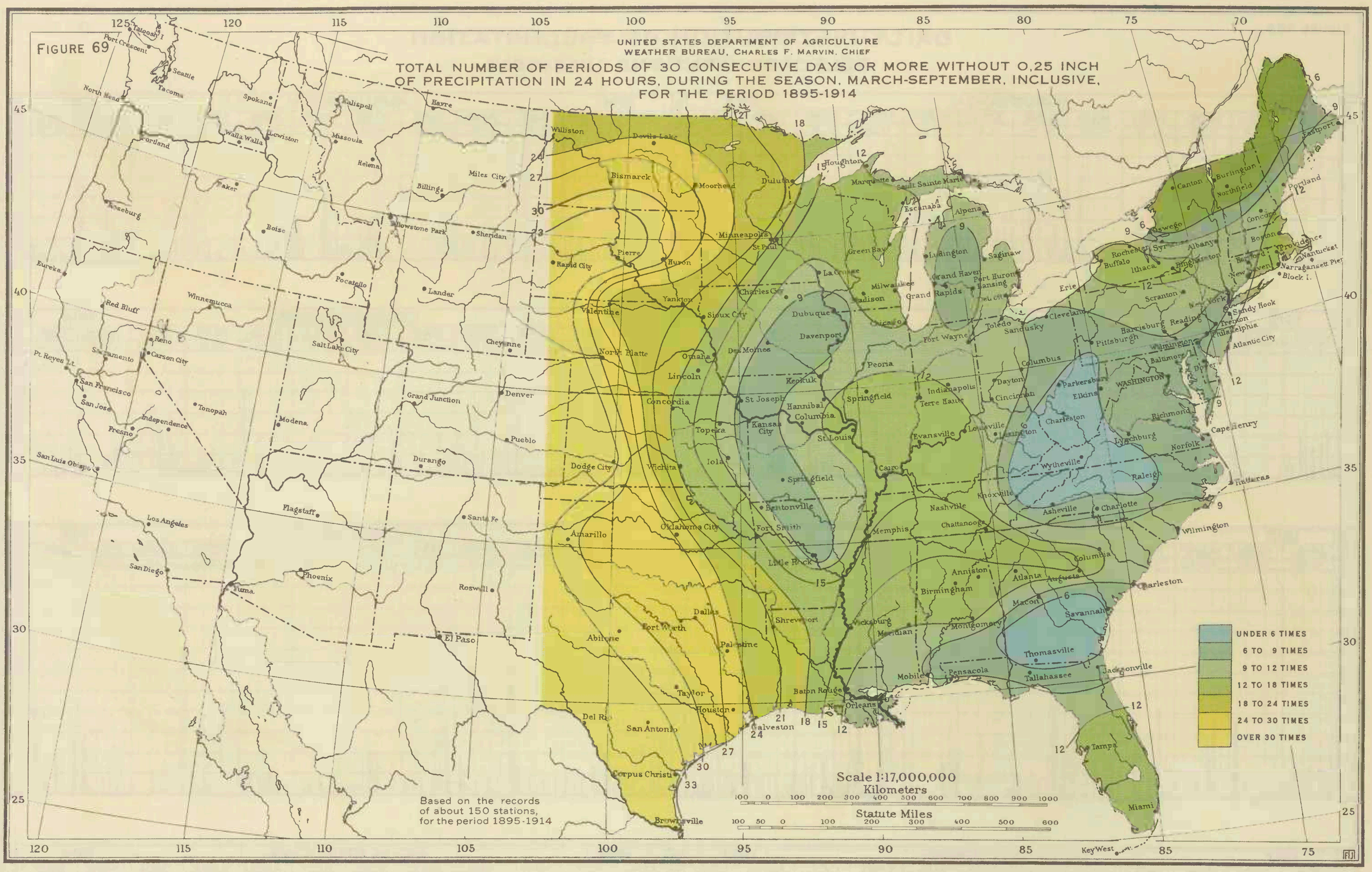


Figure 69.—This chart shows for the season from March 1 to September 30, for districts from the Great Plains eastward, the total number of periods of 30 consecutive days, or more, without one-fourth inch of precipitation in 24 hours, during the 20-year period 1895-1914. The lines are based on the records of all regular reporting stations within the districts mentioned having full 20-year records, about 150 in number. The areas having the fewest such periods of deficient precipitation are found in the Middle and South Atlantic States, the Upper Ohio Valley, and in the northern portions of New York and New England, where such droughts occurred, on the average, about once in every three seasons. Other areas of comparatively infrequent occurrence are found in western Missouri, southeastern Iowa, and in Michigan. The regions of most frequent occurrence are found in the western portions of the Plains States, where the average is nearly two such droughts in each season.

inches of annual precipitation, broadly speaking, determines the dividing line between areas where farming operations can be successfully conducted by ordinary methods and those where irrigation or other special methods are necessary, but no hard and fast rule can be laid down in this connection. With an annual precipitation of only 15 inches other conditions must be very favorable for profitable agriculture by ordinary methods. There are in Montana, eastern Washington, and elsewhere in the Northwest important grain-producing areas which receive, on the average, less than 15 inches of precipitation annually, in fact, wheat is grown in eastern Washington on only 9 inches average annual precipitation, but in these areas special care is given to conserving the moisture of the non-growing period for use during the following growing season. In the great spring-wheat region of the Red River Valley the average annual precipitation is only about 20 inches, and ordinary farming methods obtain.

In considering the moisture requirements of crops in relation to the average precipitation, not only is its seasonal distribution an important consideration, but also the amount of moisture stored in the soil at the beginning of growth, which becomes available independently of the occurrence of subsequent rainfall, must be considered, and also the portion of the rainfall received during the growing season itself which does not become available for plant growth, owing to run-off, evaporation, and other causes. Variations in the amounts of rainfall, especially droughts, are also of great importance.

The amount of stored moisture in the soil at the beginning of the growing season in much of the great grain producing Plains region is usually not large, owing to the scanty winter precipitation, and here successful crop production depends largely on the occurrence of rainfall during the period of actual growth. On the other hand, small grains in the Pacific Coast States depend largely for final maturity on the amount of moisture stored in the soil during the winter, or rainy season.

Amounts of precipitation as large as those shown in the average precipitation charts occur usually in less than half the years, and for the several months of the growing season the precipitation for about one-fourth of the years in some of the principal agricultural regions is only about one-half as much as the 20-year average. Furthermore, a considerable portion of the actual rainfall measured is of no value agriculturally, especially in regions with frequent intense rainfall. For example, 4 or 5 inches, or more, of rain may be recorded in a single day, and 15 to 20 inches in a single month, but while these heavy falls are included in computing the general averages, only a small portion of the water is available for plant development, the larger portion being lost by run-off. Thus the average amount of rainfall does not have the same agricultural significance for different sections of the country, consequently the frequency and amount of heavy rainfall in different localities, as indicated by the various auxiliary graphs and charts, should be considered in using the averages shown on the charts, also in making comparisons of one section of the country with another.

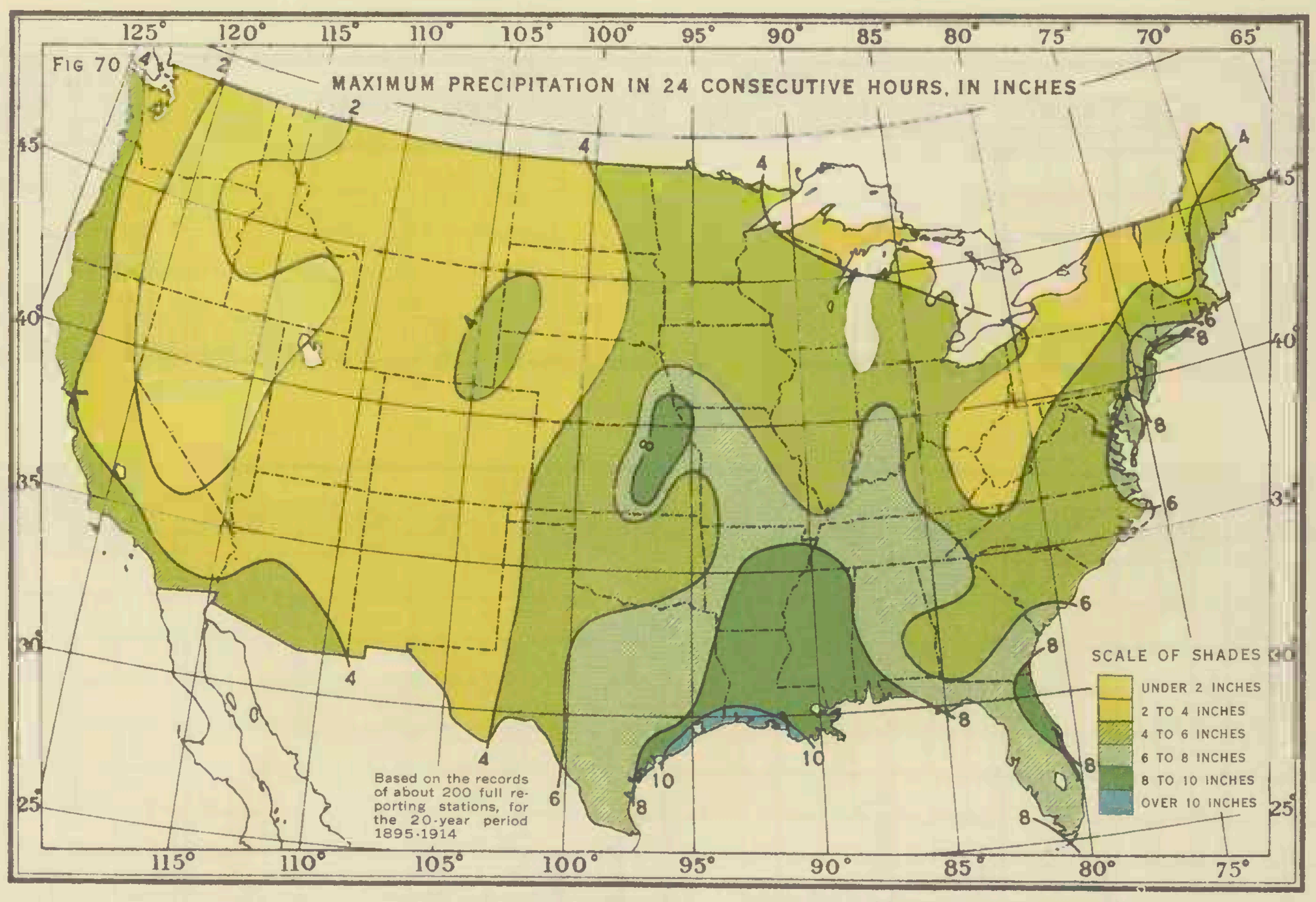


Figure 70.—This chart shows the greatest precipitation in 24 consecutive hours during the period 1895–1914. East of the Rocky Mountains the heaviest rains vary in amount in 24 hours from 4 inches in the Great Plains and Northeastern States to 10 inches along the Gulf Coast in Texas and Louisiana. On the North Pacific Coast, where the annual precipitation is heavier than elsewhere in the United States, the rainfall in 24 hours has never exceeded 5 inches.

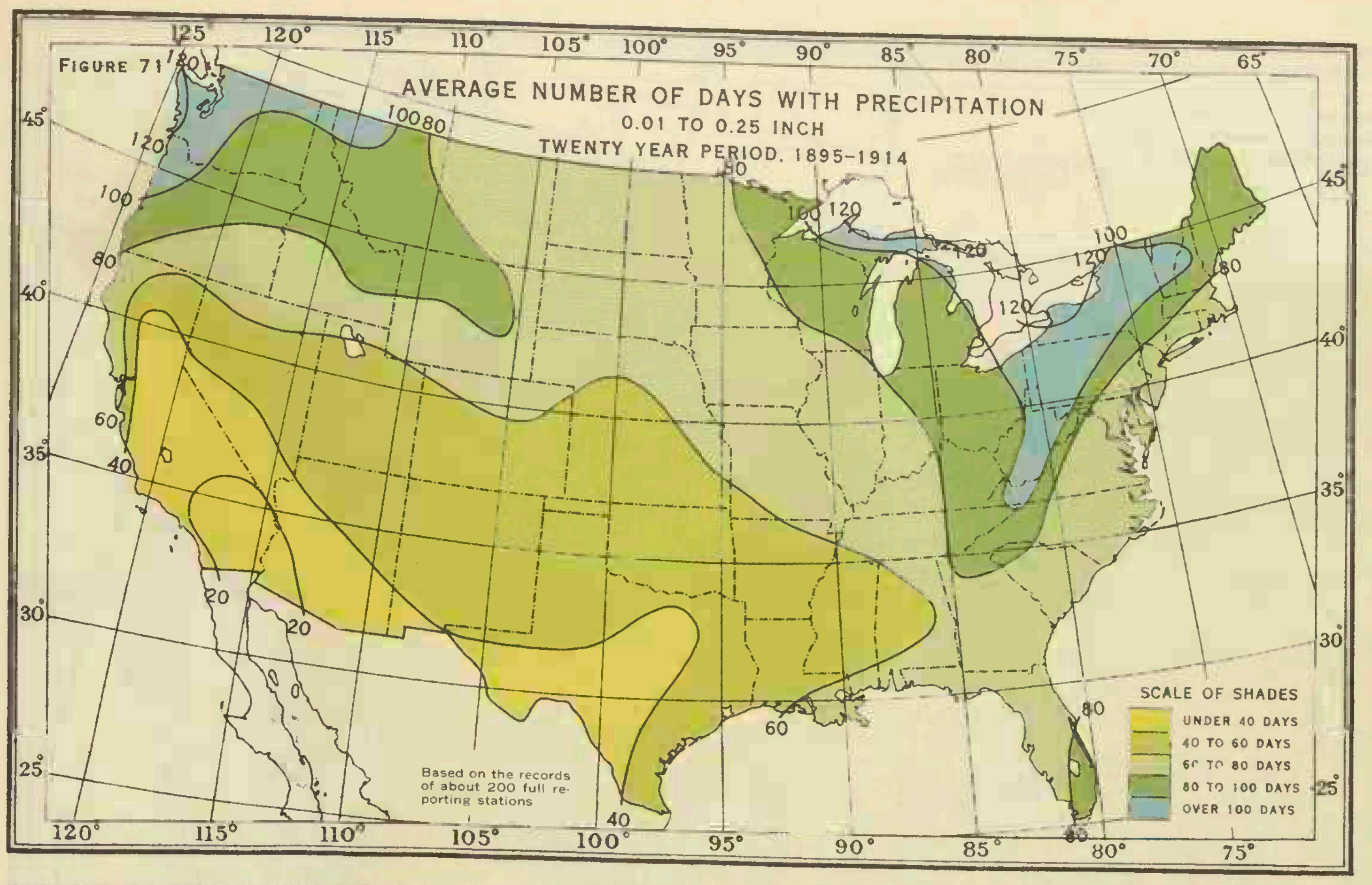
Critical periods in plant growth.—There is undoubtedly for most plants a critical period of growth, differing for species and varieties, during which weather conditions, especially rainfall, largely determine the amount of the final yield.

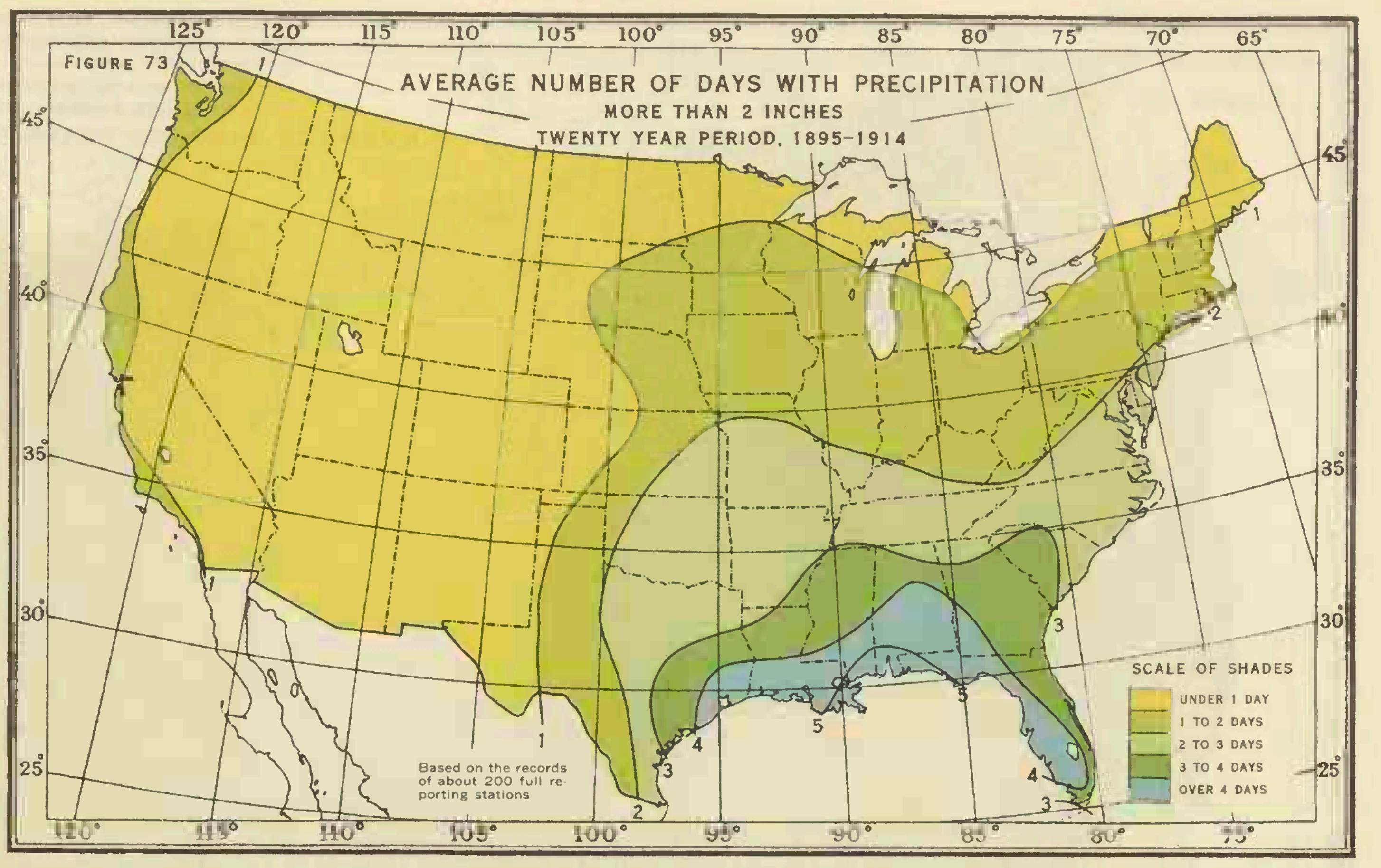
Some of the more important facts established by J. Warren Smith are as follows: In localities where temperature and sunshine are sufficient, rainfall is the controlling factor in determining plant development, and the final yields of both grain and straw, or fodder, are greatest when the soil contains from 40 to 80 per cent of its water saturation capacity during the most active period of growth, the most advantageous percentage of moisture varying for different plants and character of soil. For certain crops the critical period of growth is very short, occurring in some cases just before blossoming and in others soon thereafter. In some cases temperature seems to be the controlling weather factor and in others rainfall, varying with the crop and locality.

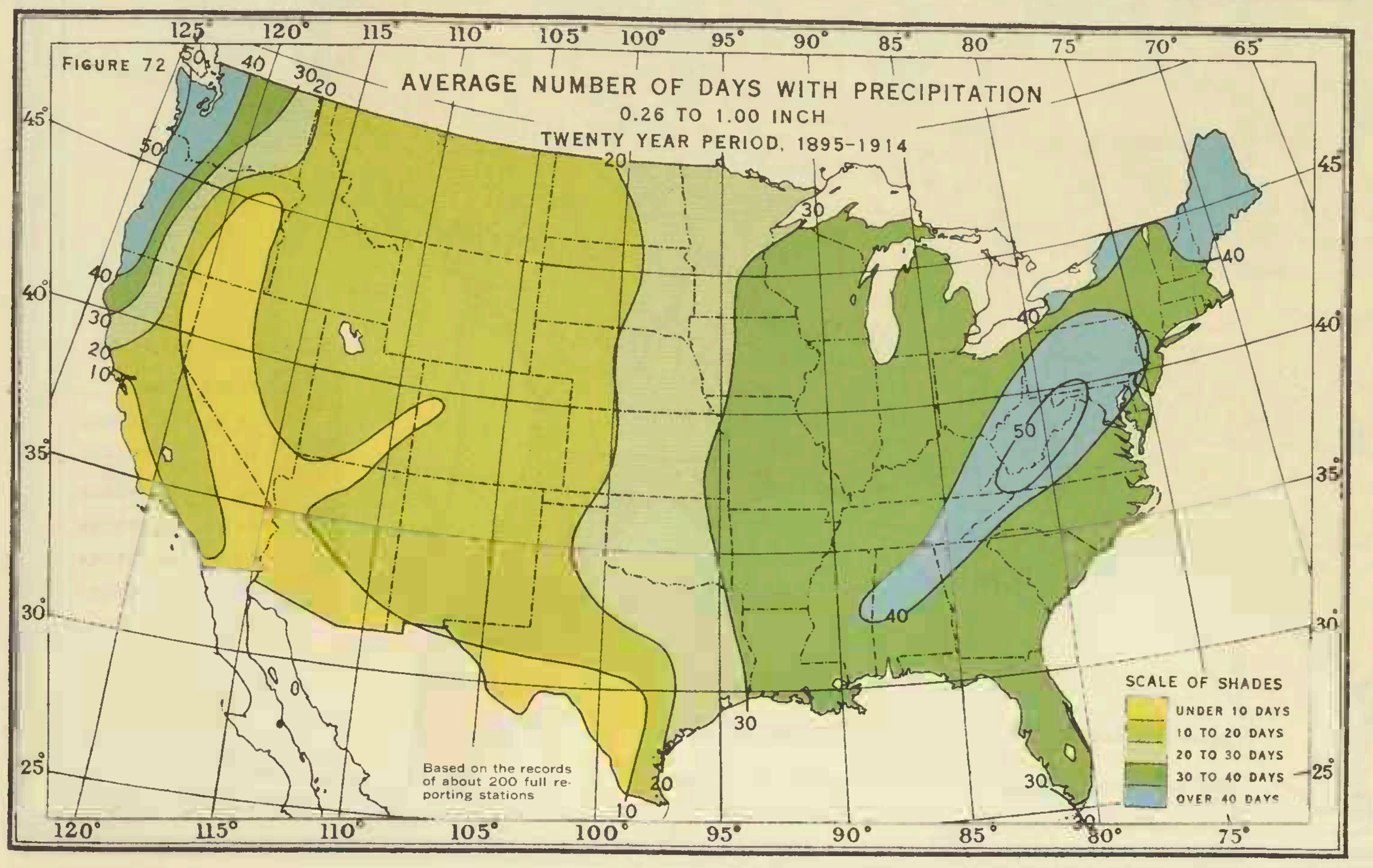
In studies of the relation between weather conditions and the yield of corn in several of the principal corn-producing States, Smith concludes that the critical period of development for that crop is comparatively brief, and that rainfall is the controlling weather factor. Considered by calendar months, the rainfall for July is the most important, but that for the period from the middle of July to the middle of August has a far greater effect upon the yield of corn than for any other similar period, while that for the 10 days following the blossoming period has an almost dominating effect on the yield, the latter varying directly with the amount of rain. In the case of potatoes in Ohio, he finds that comparatively cool and wet weather during July is most beneficial to the development of the crop.

In the case of cotton, the writer has found two critical periods very largely controlled by moisture conditions. One of these includes May and June, when too much rain, especially if accompanied by low temperature, is very detrimental to crop development; the other is in July and August, when deficient moisture, particularly when high temperatures obtain, is very injurious to the crop.

The most favorable conditions for cotton are comparatively dry and warm weather during May and June, and moderate rainfall during July, August, and early September, followed by a cool, dry fall. The most unfavorable are cool and wet weather during May and June, followed by hot and dry weather during the summer. Owing to the long period of growth and the tendency of the fields to become grassy, it is essential for best results that the weather be such as to permit thorough cultiva-







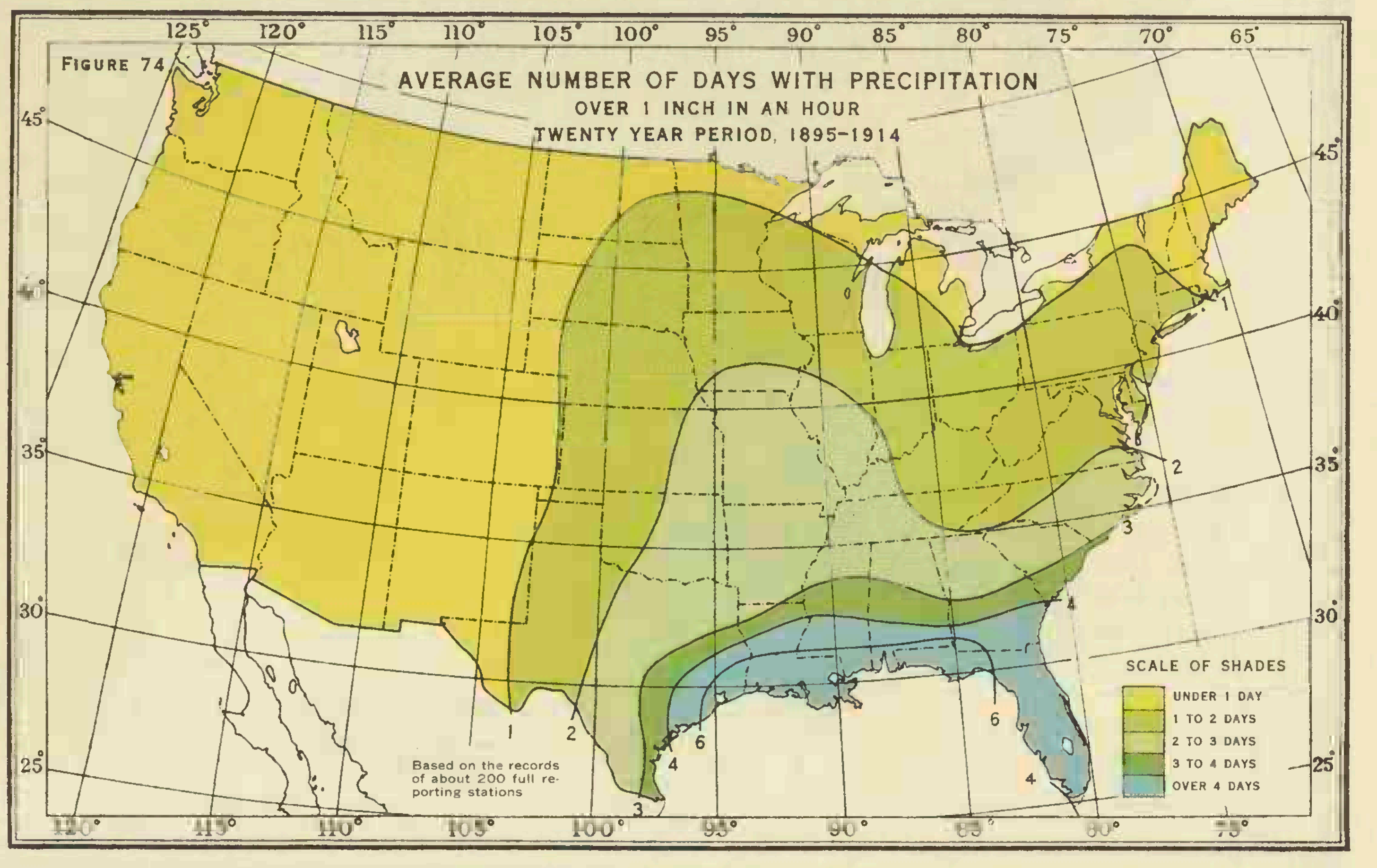


Figure 71.—The average annual number of days with light rains (0.01 to 0.25 inch) ranges from less than 20 in southeastern California to 120 days along the North Pacific Coast and in the upper Great Lakes region.

Figure 72.—The average annual number of days with moderate precipitation (0.26 to 1 inch) ranges from less than 10 in the far Southwest and in portions of the Interior Plateau region to 50 days along the North Pacific Coast and also in the central Appalachian Mountain region.

Figure 73.—The average annual number of days with more than 2 inches of rain ranges from less than one day in most of the Western States and along the Canadian boundary to five days in the central Gulf region.

Figure 74.—The average annual number ot days with over 1 inch of precipitation in an hour ranges from less than one day in the Western States and northern Great Lakes region to six days along the Gulf Coast.

tion of cotton during the spring months; too much rain prevents this, and, in addition, such a condition encourages shallow root growth, which proves disastrous if a severe drought follows.

Day and night rainfall.—The inset chart, figure 9, accompanying the map of warm-season precipitation, shows for the 6-month period, April to September, inclusive, the percentage of rainfall occurring between 8 p. m. and 8 a. m., seventy-fifth meridian time. This inset chart is based on records of about 175 regular Weather Bureau stations, covering the full 20-year period 1895–1914.

Rainfall during much of the crop-growing season is largely the result of thundershowers, and droughts of more or less severity are of rather frequent occurrence, but more so in some sections of the country than in others. During periods of deficient rainfall, whether or not showers of small or moderate amounts result in permanent benefit to growing plants depends largely upon the time of their occurrence, whether in the heated period of the day or the comparatively cool night hours. If in the former, the hot sunshine, which frequently is in evidence immediately after summer daytime showers, causes rapid evaporation and often crusts the cultivated surface, in which case little or no benefit is derived from the shower and actual harm may result. On the other hand, when showers occur at night, evaporation is less active, the moisture penetrates the soil to a greater depth, a crust is less likely to form, and a maximum of benefit is derived.

The quantitative relation between day and night rainfall is also of considerable agricultural significance from the viewpoint of interruption to farm work. While rainfall is indispensable to the farmer, it nevertheless entails a loss of time for labor of no small proportions in the aggregate, and as the amount of time so lost by reason of rainy weather varies greatly in different sections of the country, a knowledge of this variation becomes of considerable importance from the standpoint of economical production.

East of the Rocky Mountains there are wide variations in the matter of day and night rains. The region of maximum day rainfall is found in the Southeastern States, where at some places about 75 per cent of the total rainfall for the 6-month period occurs between the hours of 8 a. m. and 8 p. m., seventy-fifth meridian time. From this locality northward and westward there is a progressive and comparatively uniform decrease in the proportion of day rains until the other extreme is reached in the Plains region. Here, from 60 to 65 per cent of the warm season rainfall occurs during the hours from 8 p. m. to 8 a. m., seventy-fifth meridian time. Figures 16 and 17 show for Lincoln, Nebr., representing the region of dominant night rains, and Thomasville, Ga., representing that in which day rains are of greatest relative amount and frequency, the average hourly rainfall, local standard time, for the period April to September, inclusive, and also the average hourly frequency of rains. The diagrams comprised in this figure show also for the stations mentioned and for Evansville, Ind., the percentages of the total rainfall and total duration of rains occurring during the respective day and night periods for each of the six months. The record of Evansville is introduced to show conditions for regions in which the night and day rainfalls are of approximately equal amount.

In this connection it is of interest to note that the region of dominant night rainfall is one in which a large amount of wheat is grown, and also that the greatest concentration of night rains comes in the harvest season. The advantages of this nocturnal concentration can not be overestimated, as otherwise great difficulty would be experienced in harvesting and thrashing the immense crop grown. The Plains region is also one of great importance in corn production and the frequent night showers in those districts undoubtedly contribute largely to making it such.

West of the Rocky Mountains the summer rainfall is about equally divided between day and night, except that in the Arizona type there is a marked afternoon concentration. In most of the western districts the question is not of special importance, however, as precipitation is usually light and in large areas negligible.

Frequency and intensity of precipitation.—In studying the relation of precipitation to plant development, the question of frequency of occurrence and intensity of fall becomes of great importance. The average precipitation in a given locality may be considerably less than in some other, but the rains may be better distributed and less torrential, which would largely offset the difference in actual amounts. Only the water actually absorbed by the soil can be utilized in plant development, and therefore in using charts of average rainfall the frequency and intensity should be known, as they are indicative of the probable proportion of the actual precipitation that finally becomes available for growing plants.

Accompanying the charts of average seasonal and monthly precipitation there are others that show for the several months and seasons the frequency of occurrence, as indicated by the average number of days on which precipitation to the amount of 0.01 inch or more occurs. It will be noted, for example, by referring to these charts that while the average amounts of precipitation over the eastern sections of the country increase from the Northern States southward to the Gulf region, the frequency of occurrence often increases in the opposite direction, from south to north, this condition being especially marked during the spring months. Thus, where the total precipitation is comparatively small, rain often occurs at shorter intervals, which largely compensates for the smaller amount. This is, of course, not a general rule applicable to all parts of the country and seasons of the year. In the western semiarid sections, where the precipitation is very light, there is also a correspondingly small number of days with rain, and where it is heavy, as along the North Pacific Coast, the number of rainy days is large.

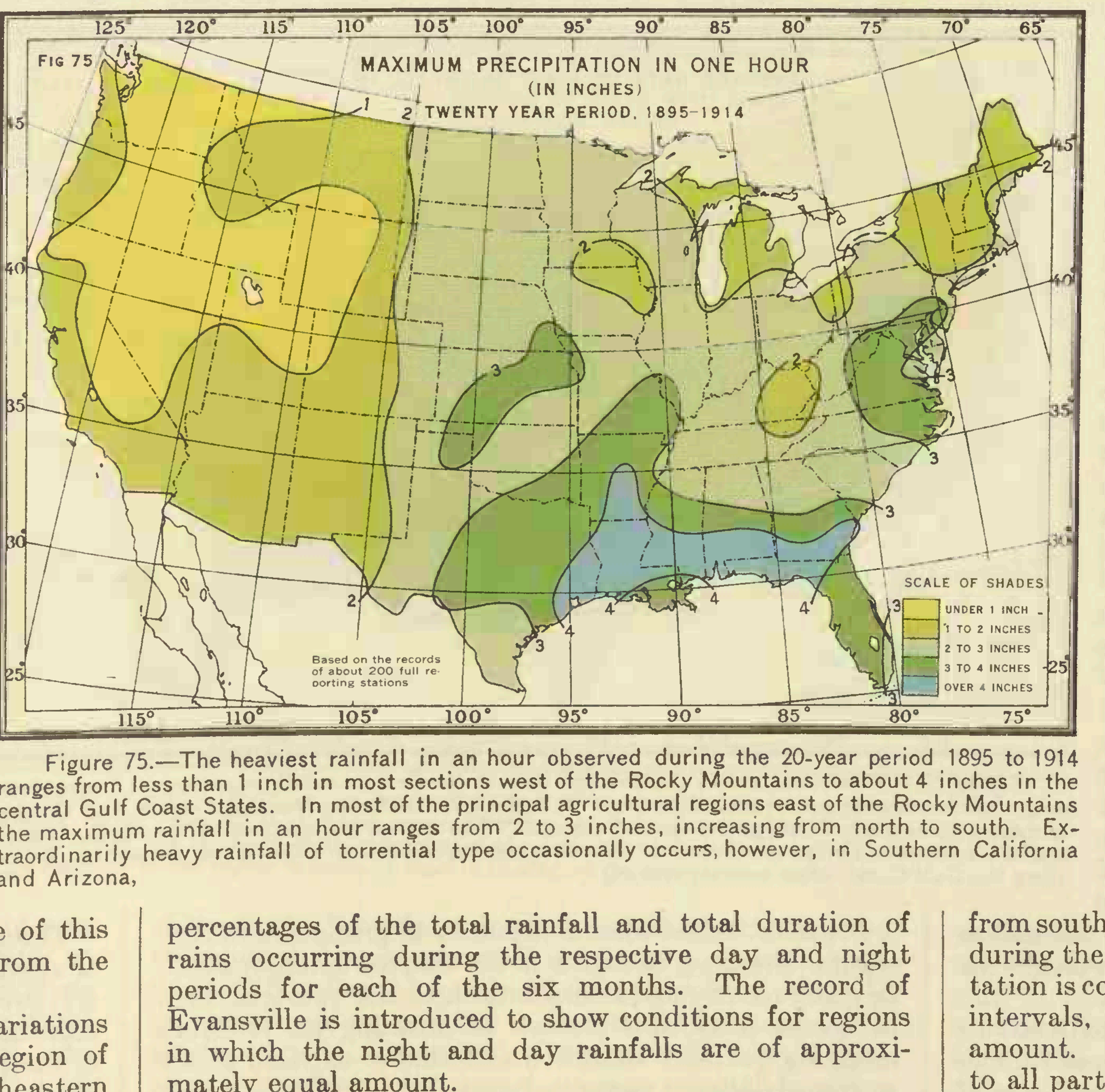


Figure 75.—The heaviest rainfall in an hour observed during the 20-year period 1895 to 1914 ranges from less than 1 inch in most sections west of the Rocky Mountains to about 4 inches in the central Gulf Coast States. In most of the principal agricultural regions east of the Rocky Mountains the maximum rainfall in an hour ranges from 2 to 3 inches, increasing from north to south. Extraordinarily heavy rainfall of torrential type occasionally occurs, however, in Southern California and Arizona.

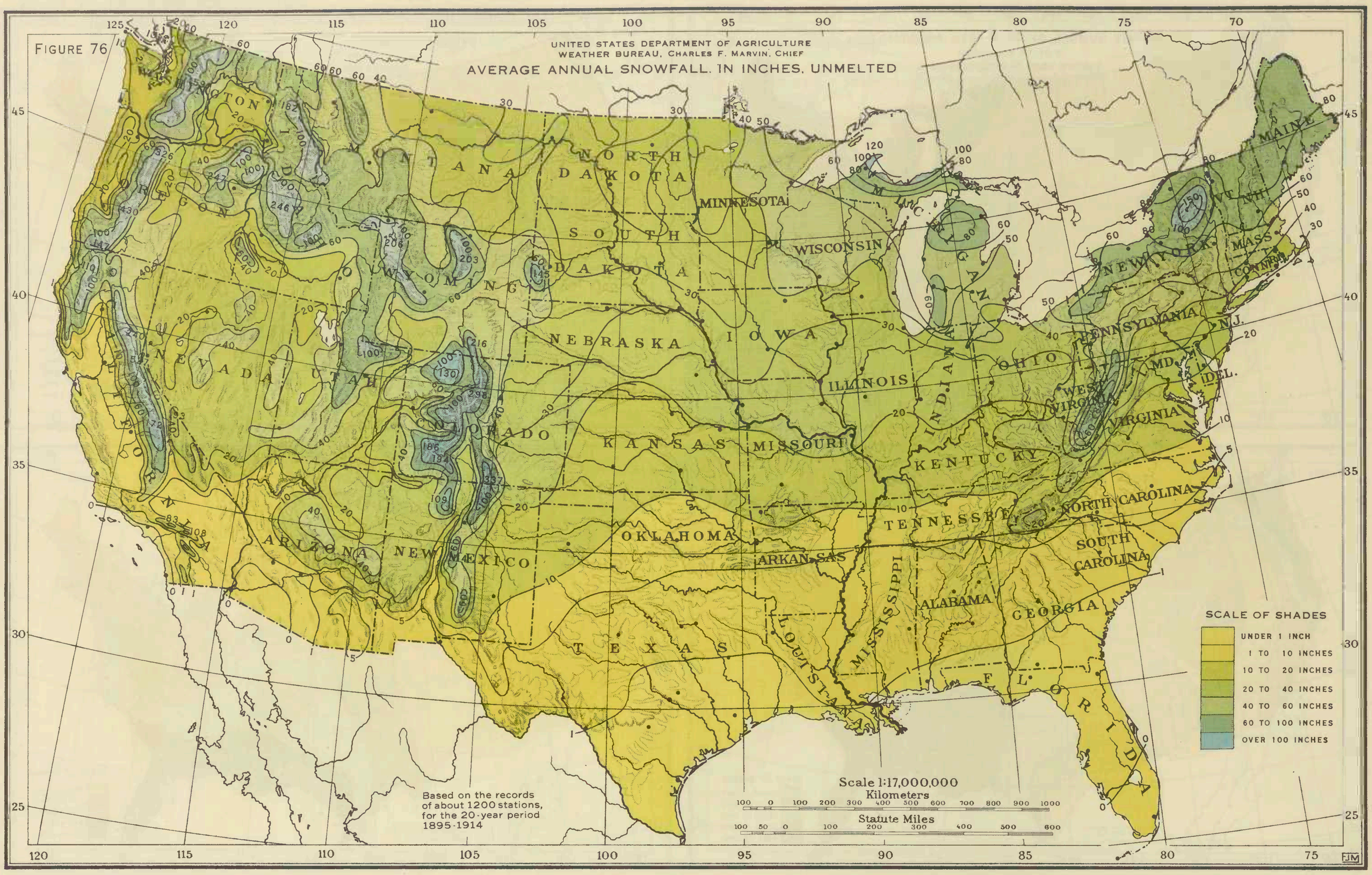


Figure 76.—This chart shows the average annual snowfall in inches unmelted. East of the Rocky Mountains lines have been drawn at 1 inch and for each 10 inches of snowfall, but in the western mountainous districts snowfall conditions are so varied that wider intervals had to be used and the areas are broadly generalized. Here figures also have been entered on the map to show the average amount at as many localities as practicable. The heaviest snowfall in the United States occurs in the mountains of the Pacific Coast States, where in some localities the averages are as much as 400 to 500 inches. In the Rocky Mountains snowfall is not so heavy as in the Sierra Nevadas and Cascades, but here also large amounts frequently occur, some of the western slopes receiving from 200 to 300 inches, or more. East of the Rockies the heaviest snowfall occurs in the northern border States from Michigan to New England. In some localities in these Northeastern States from 120 to 150 inches occur annually on the average. The amounts decrease rapidly southward to the Gulf region, where snowfall is usually negligible in amount.

West of the Rocky Mountains, for the winter season as a whole, December to February (fig. 27), the total number of rainy days varies from about 5 or 6 in southwestern Arizona and the adjoining portions of California and Nevada to about 60 days along the North Pacific Coast. Over the western portion of the Plains region, extending from the Canadian boundary to the Mexican border, there are about 10 days with precipitation during this period. To the eastward there is a progressive increase in the frequency of precipitation to from 30 to 40 days in the region just west of the Appalachian Mountains, but in the Middle and South Atlantic States the number is smaller, especially in the Florida Peninsula.

For the spring season, March to May (fig. 37), the number of rainy days is materially less than for winter in the Pacific Coast States, and also in the central and east Gulf region, but over the Great Plains precipitation occurs much more frequently, the number of days for the season ranging from about 20 in the western portion to about 30 in the eastern.

During the summer season, June to August (fig. 47), the average frequency of rainfall is comparatively uniform over most districts east of the Rocky Mountains, there being generally for the season from 20 to 30 days with rain throughout the Mississippi Valley and 30 to 40 days to the eastward. In much of California there is on the average only about one day with rain for the entire three months, but this increases northward to about 20 days along the Washington coast.

During the three fall months, September to November (fig. 57), rainfall is less frequent in most eastern districts than in the other seasons, the number of rainy days for this period east of the Rocky Mountains ranging generally from about 10 to 20, except in the Great Lakes region and Ohio Valley and also over the Appalachian Mountain region and in the Northeastern States, where precipitation is of more frequent occurrence. In the Pacific Coast States the number of rainy days for the season ranges from 10 or less in central and southern California to more than 40 along the Washington coast.

Figure 68 shows graphically for eight selected stations the daily rainfall for each of the four years from 1911 to 1914. It indicates in a general way for the localities of the respective stations the distribution of precipitation throughout the year and also the irregularities of the intervals between rains.

The relative intensities of rainfall for short periods of time in different portions of the country are shown by figures 70 to 75. Figure 71 shows the annual average number of days with precipitation from 0.01 to 0.25 inch, figure 72 shows the average annual number with 0.26 to 1 inch, figure 73 shows the average annual number of days with more than 2 inches, and figure 74 the average annual number with more than 1 inch in an hour. Figure 75 shows the maximum precipitation in one hour during the entire 20-year period 1895 to 1914, and figure 70 the maximum in 24 hours during the same period. These charts indicate the frequency of light and of heavy rainfall in different sections of the country.

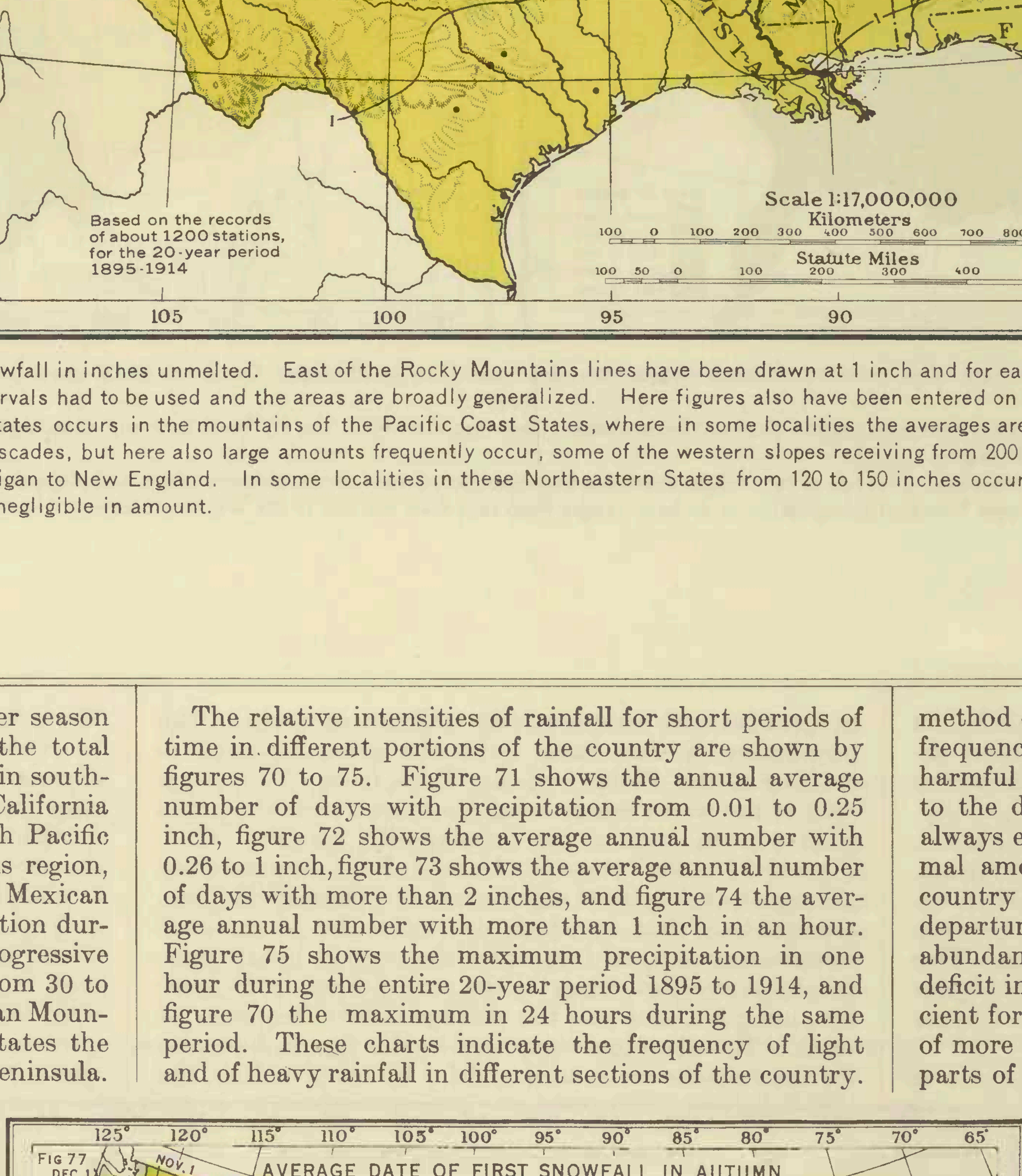


Figure 77.—This chart shows the average date of the first snowfall in autumn. These dates range from somewhat earlier than September 16, locally, in the Rocky Mountain region, and October 1 in extreme northern Michigan, to about December 16 in the central portions of the South Atlantic and Gulf States. To the southward of this line the occurrence of snow is very irregular, or, as along the Gulf Coast, often entirely lacking.

Droughts.—Just what deficiencies in precipitation constitute damaging droughts is not easy of determination, as many modifying factors enter into the question, such as temperature, soil texture as affecting its moisture retaining qualities, condition and kind of exposed plants as regards critical periods of growth and drought resisting qualities, moisture condition of the soil at the beginning of the period of deficient rainfall, and others. It is likewise difficult to determine the most satisfactory method of presenting precipitation data to show best the frequency of occurrence of deficient rainfall that may be harmful or disastrous to growing crops. Statements as to the departures from the average amounts are not always entirely satisfactory, for the reason that the normal amounts vary greatly in different sections of the country and consequently a given percentage of minus departures for an extended period in a region of usually abundant rainfall would not be so serious as a similar deficit in one where the average amount is barely sufficient for the development of the staple crops. Droughts of more or less severity occur at irregular intervals in all parts of the United States and they may affect areas of considerable extent, but one never covers the entire country. On the other hand, they may be extremely local, affecting only a county or even part of a county.

The frequency of periods of subnormal rainfall for the different portions of the country and the magnitude of deficiencies are shown graphically by several methods in the accompanying charts and diagrams. A dot map, figure 15, shows for a large number of representative and well-distributed stations the monthly distribution of precipitation for different sections of the country for each month of the entire 20-year period 1895 to 1914. The frequency of subnormal monthly precipitation in different localities can readily be seen from these graphs. Figure 7 shows for the entire country the relative number of times in the 20-year period 1895 to 1914 that the annual precipitation was less than 85 per cent of the average; figure 11 shows the relative number of times the warm season amount, April to September, inclusive, was less than 75 per cent of the average, while figures 58 to 65 show for each month from March to October, inclusive, the relative number of times the monthly totals were less than 50 per cent of the average. These charts are based on the records of about 600 well-distributed stations.

There are wide variations in the frequency of periods of subnormal rainfall in different portions of the country, even in comparatively small areas in close proximity, especially when monthly periods are considered. West of the Rocky Mountains the charts show very large percentages, particularly in the summer season, because the monthly amounts in those districts are usually very small and the averages are unduly magnified by the occasional occurrence of comparatively heavy rainfall.

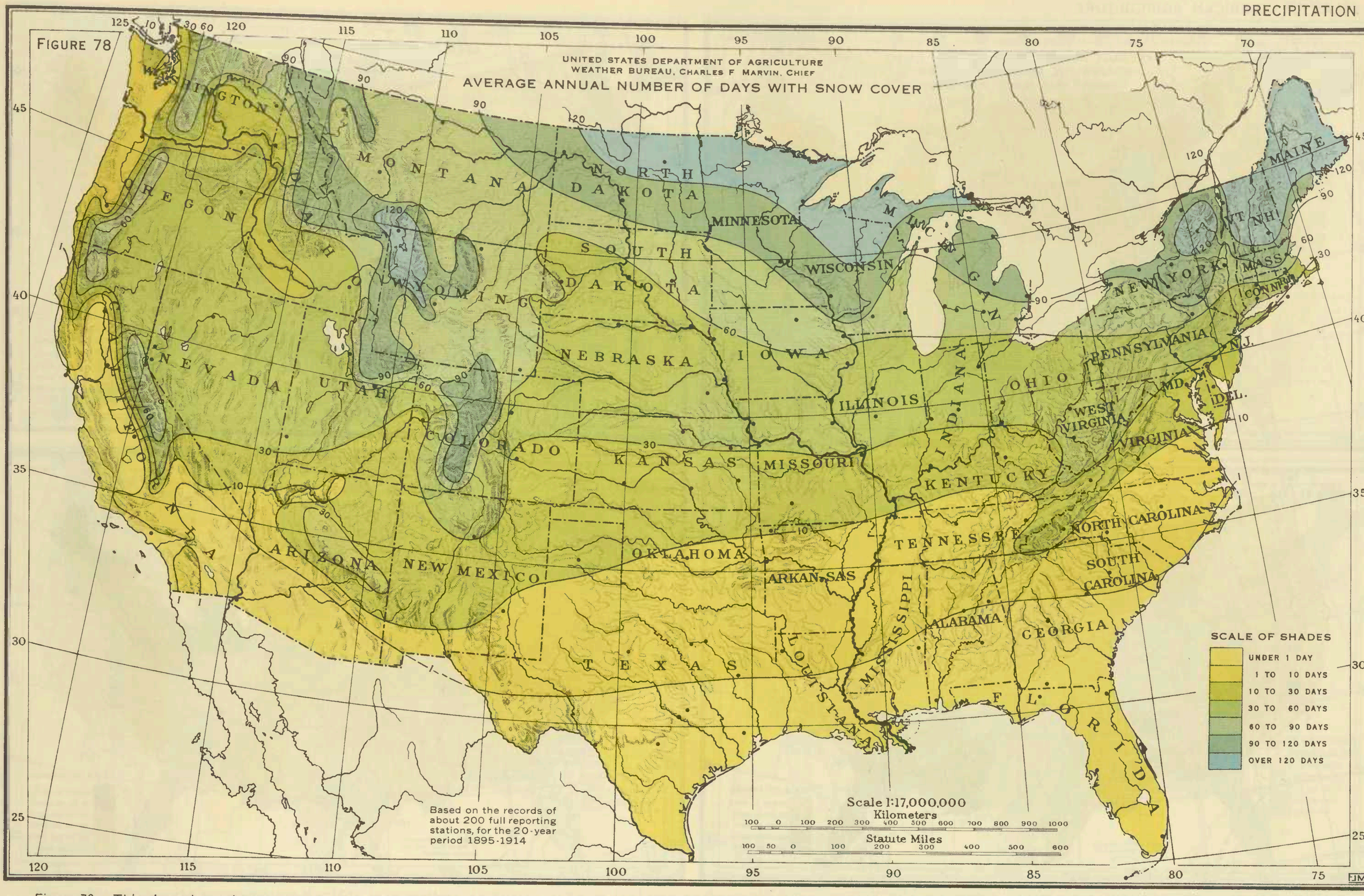


Figure 78.—This chart shows the average annual number of days with snow cover; that is, the average number of days during which the ground is covered with snow, but not necessarily consecutive days. The chart indicates the duration of protection afforded fall-sown grains by snow cover in different sections of the country. East of the Rocky Mountains the average number of days with snow on the ground during the season decreases with considerable regularity from about 120 along the northern border to one day in the central portion of the Gulf States. From the Rocky Mountains westward the data refer only to the lower altitudes, no attempt having been made to show conditions in the more elevated districts.

Figures 66 and 69 show for the districts east of 103° west longitude the number of times in the season, March to September, inclusive, that precipitation to the amount of 0.25 inch in 24 hours did not occur for 20 or more consecutive days and for 30 or more consecutive days, respectively; while figure 67 shows for the same season and for each of the 20 years at selected stations, arranged by geographic districts, the longest period of consecutive days during which precipitation to the amount of 0.25 inch in 24 hours did not occur. These charts are based on the records of all full-reporting stations in the districts covered, about 100 in number, for the 20-year period 1895–1914.

SNOWFALL.

Figure 76 shows the average annual snowfall unmelted, in inches, for the United States. East of the Rocky Mountains lines have been drawn in most cases for each 10 inches, but in the western mountainous districts snowfall conditions are too varied to permit of a satisfactory presentation of the data by this means. The difficulties in depicting the precipitation of these districts, which includes melted snow, have previously been pointed out. The water equivalent of snow varies with its physical condition, whether moist or dry, and the ratio may have a range of from 1 to 5 to 1 to 15 or even less. In addition, precipitation often occurs in the valleys in the form of rain and on the mountains as snow, which makes the differences in snowfall between the valleys and adjacent mountains much larger than the actual difference in precipitation. As an indication of the magnitude of the difference in the amount of snowfall that may occur in near-by localities, owing to topographic influence, the records at Electra and Tamarack, Cal., may be cited. Electra is situated in Amador County at an elevation of 725 feet above sea level. At this station the average annual snowfall for the 10-year period 1906–1915 was about 1 inch. Tamarack is located some 50 miles to the eastward, in Alpine County, but at an elevation of about 8,000 feet, and here the average annual snowfall for the same period was about 42 feet, the amounts being in the ratio of about 1 to 500. In view of these facts no attempt was made to draw lines of equal snowfall in detail for the western districts, and here the areas inclosed by the various lines are broadly generalized. The annual average amounts of snowfall have been entered numerically for as many localities as practicable.

More or less snow occurs in all portions of the United States, except in southern Florida and at the lower elevations in southwestern Arizona and southern California. Snow is of common occurrence at the higher altitudes in California but is practically unknown along the immediate coast south of latitude 42°.

The greatest known snowfall in the United States occurs on the west or windward side of the Sierra Nevada and Cascade ranges in the Pacific Coast States, where at some places average amounts of 400 to 500 inches or more are of record. At Summit, Cal., situated in a pass of the Sierra Nevada at an elevation of about 7,000 feet, the annual average snowfall is in excess of 400 inches, while 697 inches, or nearly 60 feet, have been recorded in a single season and 298 inches, or about 25 feet, in a single month. Tamarack is about 1,000 feet higher than Summit and its annual average snowfall is about 100 inches greater. At some places to the northward, over the western slopes of the Cascade Range in Oregon and Washington, from 300 to 400 inches or more of snow occur each year on the average, but to the leeward of those mountains the lower altitudes receive only from 12 to 20 inches.

In the Rocky Mountains snowfall is not so heavy as in the Sierra Nevada and Cascade ranges, but here also large amounts frequently occur, especially on the western slopes. In Colorado the average annual amounts at some of the higher elevations reach 300 inches and at similar locations in northern New Mexico and in Wyoming about 200 inches occur. In some mountainous districts of Idaho the average snowfall is also about 200 inches.

East of the Rocky Mountains the regions of heaviest snowfall are to be found in portions of the Upper Peninsula of Michigan, where the average annual amounts reach 120 inches or more, and at places in the Adirondack Mountains in New York, where 150 inches or more occur on the average. There is also an area of heavy snowfall over the central section of the Appalachian Mountains, including western Maryland and portions of West Virginia, where from 80 to 100 inches are received annually on the average. From these heavy snowfalls in the northern border States and mountainous regions there is a rapid decrease southward to about 20 inches in central Virginia and the southern portions of Ohio, Indiana, and Illinois, and thence a less rapid decrease to the Gulf States, where the amount of snowfall is usually negligible. Over the Great Plains the average annual snowfall ranges generally from about 1 inch in central Texas to about 20 inches in northern Kansas, while farther north from 20 to 30 inches are received.

Figure 78 shows the average annual number of days with snow cover; that is, the average number of days in the winter season during which the ground is covered with snow, but not necessarily consecutive days. This chart shows the relative protection usually afforded fall-sown grains by snow cover in different sections of the country. East of the Rocky Mountains the average number of days with snow cover decreases with considerable regularity from about 120 along the northern border to 1 day in the central portions of the Gulf States. From the Rocky Mountains westward the data refer only to the lower altitudes and no attempt has been made to show the number of days with snow cover in the more elevated regions.

Figure 79 shows the average annual number of days with snowfall (0.01 inch or more, melted), and figure 77

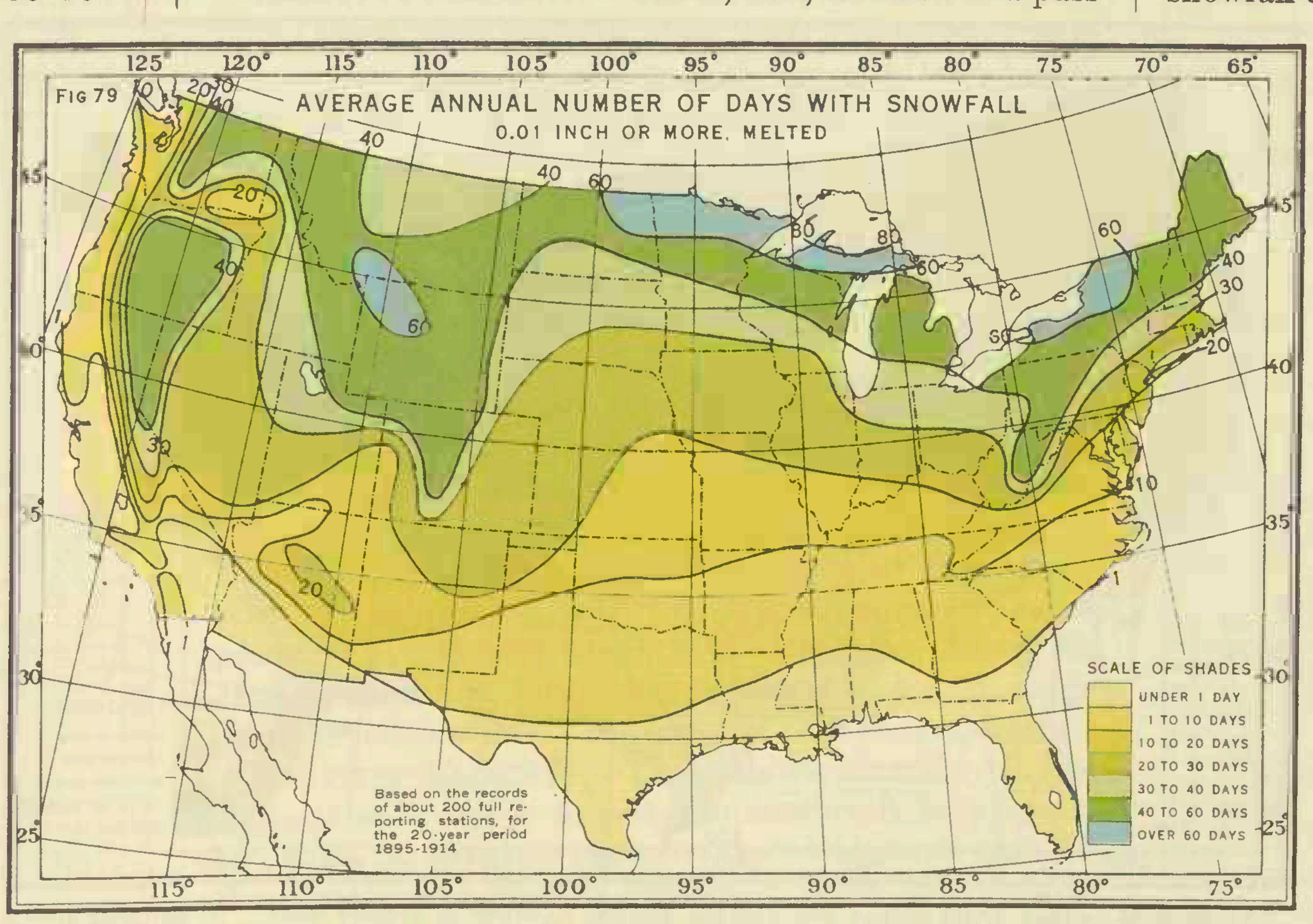
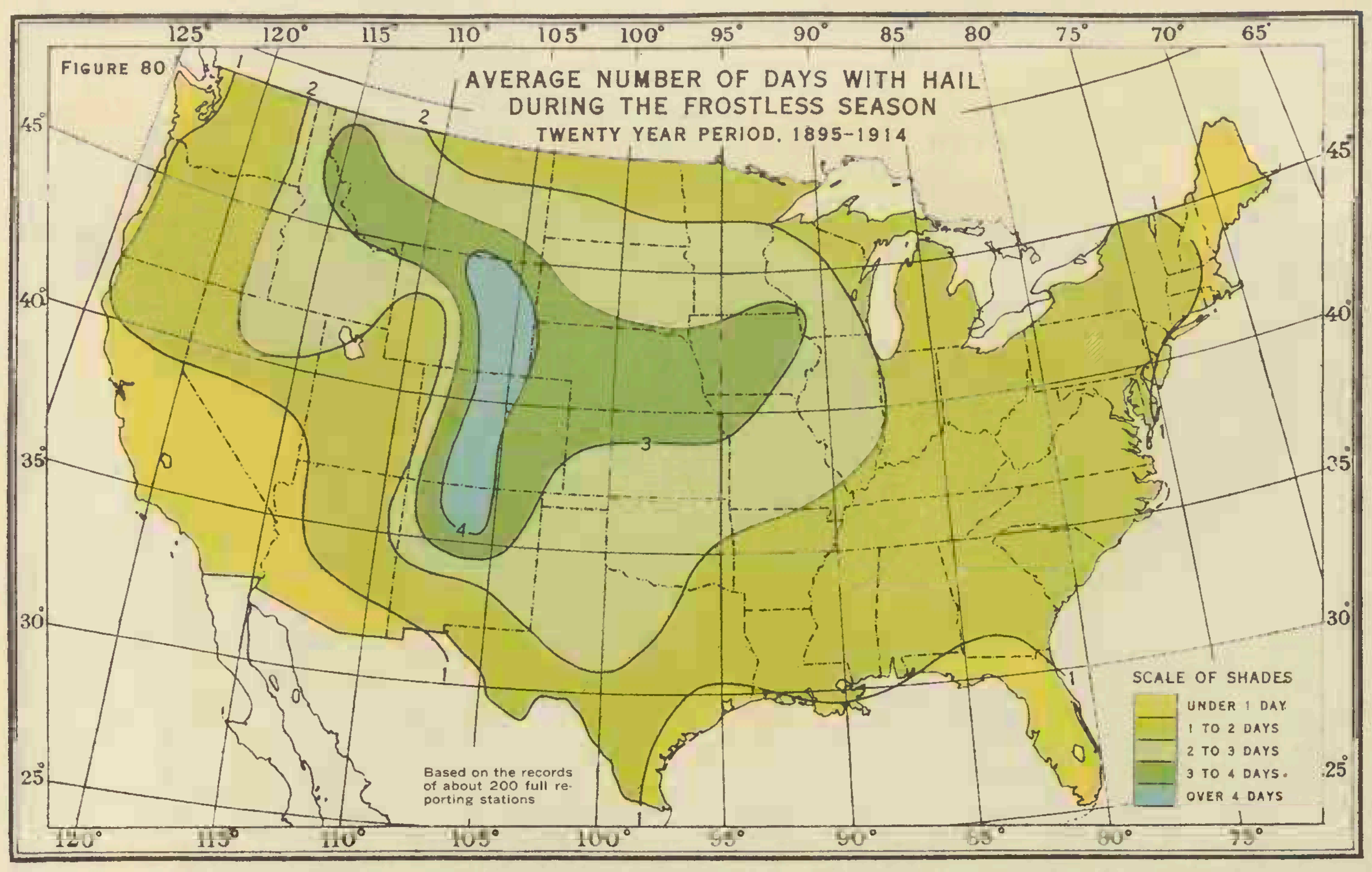
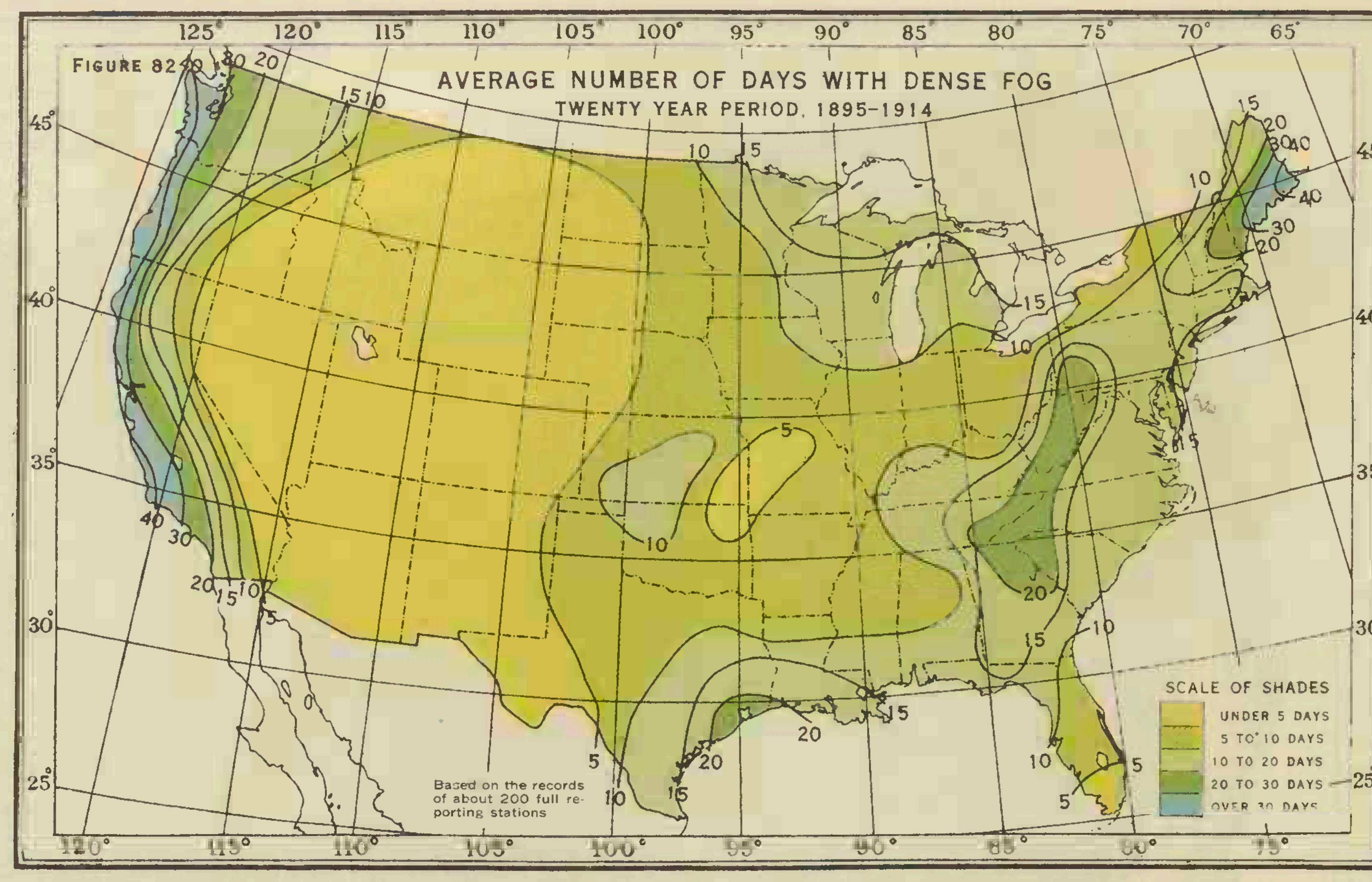
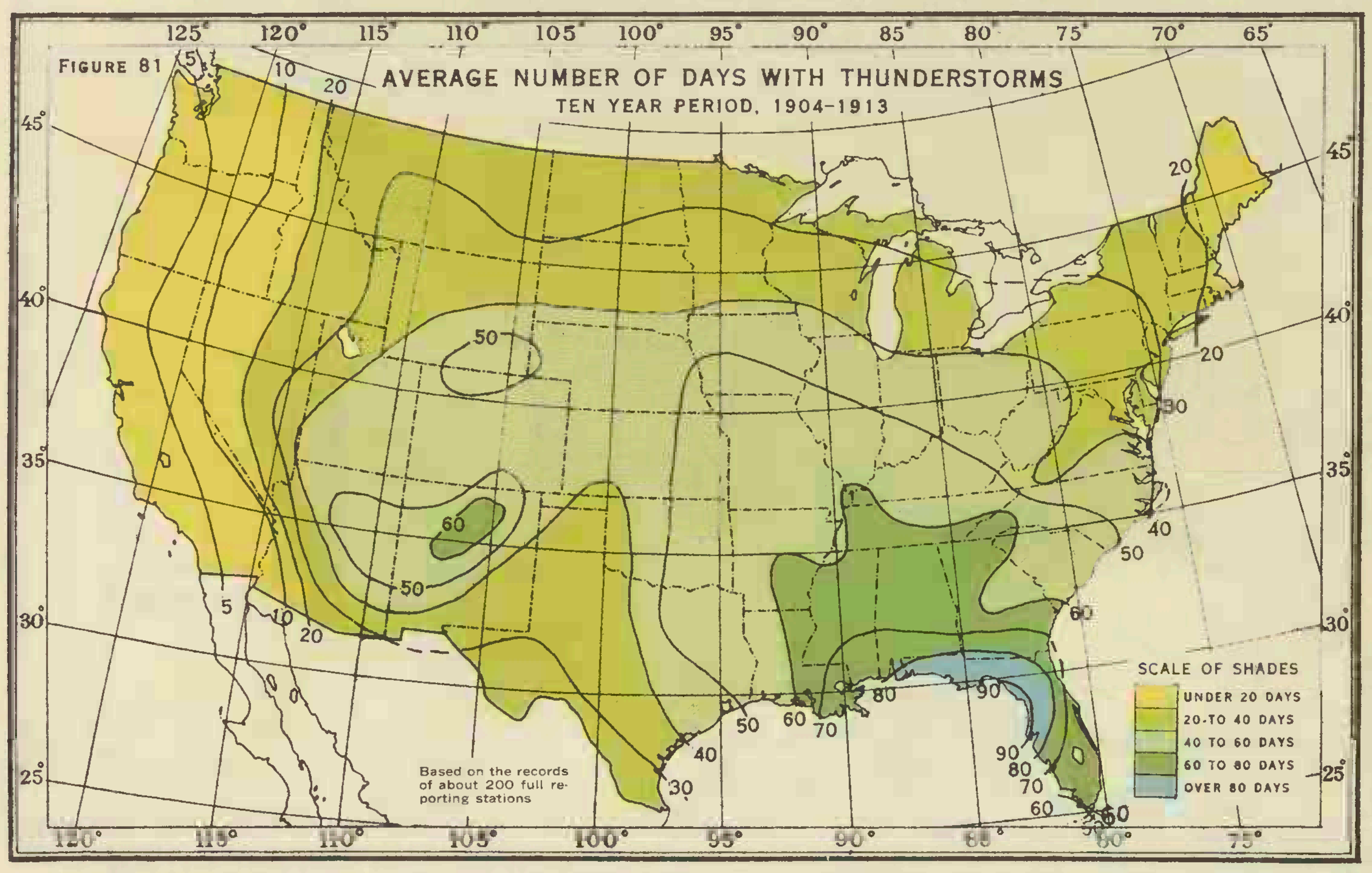


Figure 79.—This chart shows the average annual number of days in which snow falls. The number varies from 80 in extreme upper Michigan to 1 day in the central portion of the Gulf States. From the Rocky Mountains westward the data refer only to the lower altitudes, snow being more frequent in the higher mountains than indicated on the chart.







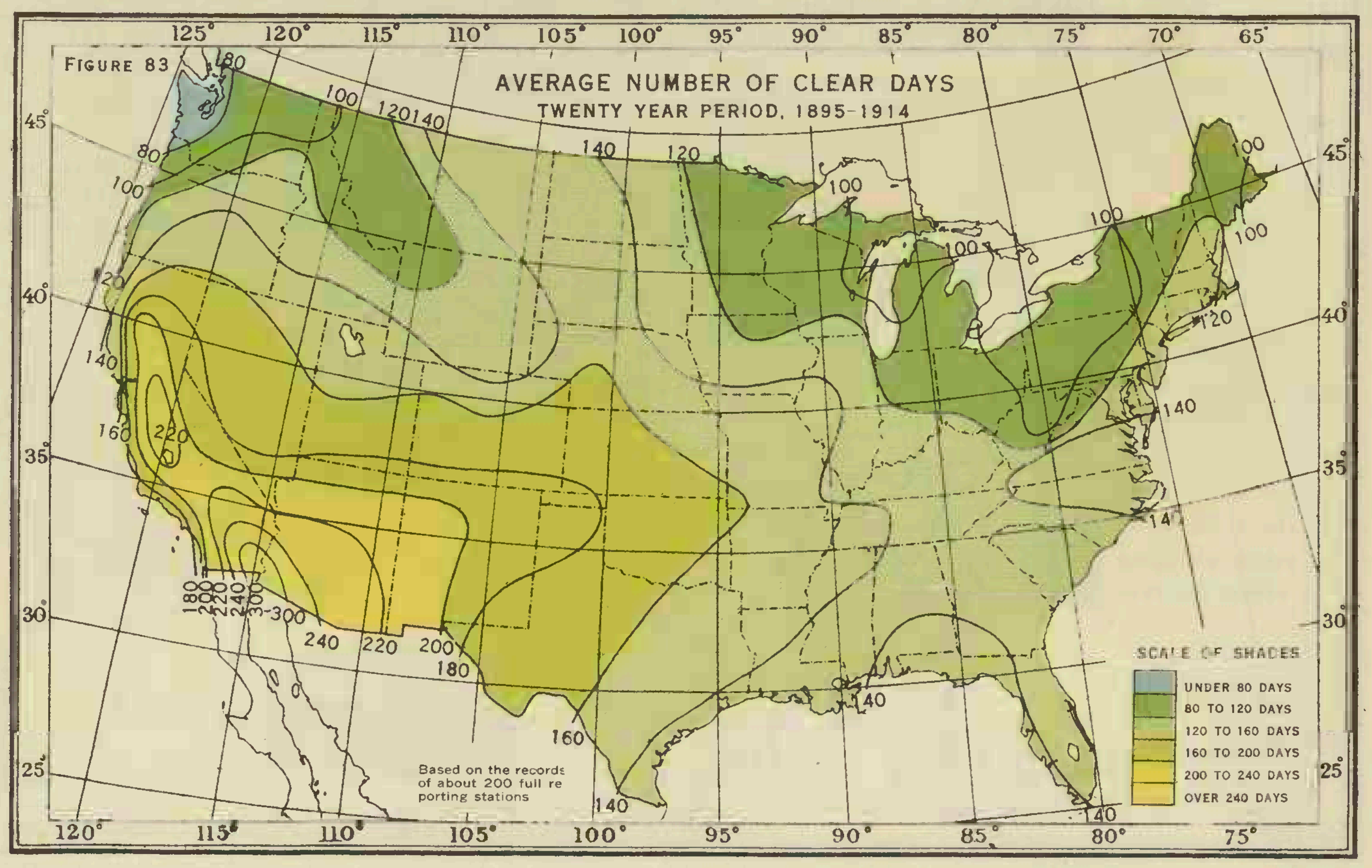


Figure 80.—This chart shows the average annual number of days with hail between the time of last killing frost in spring and the first in autumn. The length of the season on which the chart is based varies for different sections of the country and for each year, corresponding with the length of the frostless season.

Figure 81.—Thunderstorms are rare in the Pacific Coast States, where they occur, as a rule, on less than five days in the year. They are of greatest frequency along the west coast of the Florida Peninsula.

Figure 82.—Fog is of most frequent occurrence along the Pacific Coast and the northern portion of the Atlantic Coast. Dense fog occurs along these coasts, on the average, during more than 40 days of the year. In the interior districts west of the Appalachian Mountains fog is infrequent, especially in the Rocky Mountain and Interior Plateau regions, where it occurs, as a rule, on fewer than five days annually.

Figure 83.—This chart shows the average annual number of clear days. Cloudy weather occurs with greatest frequency along the North Pacific Coast and in the region of the Great Lakes, where there are, on the average, fewer than 100 clear days during the year. In portions of the far Southwest 300 or more days of the year are clear.

the average date of the first snow in autumn. In these cases, also, the data for the Western States refer only to the lower levels.

HAIL.

Figure 80 shows the average annual number of days with hail during the frostless or crop-growing season, based on the records of all full reporting stations for the 20-year period 1895–1914. The length of the season covered by this chart for different localities is not the same, as the period between the last killing frost in spring and the first in fall has been considered in each case, and this period varies with latitude, altitude, etc. Hail occurs with much greater frequency in the Plains States and the Rocky Mountain region than in other portions of the country. In central and southern California and along the immediate Atlantic and Gulf coasts it seldom occurs, and, in general, it is infrequent east of the Mississippi, occurring in these districts on the average only about once during the frostless season of each year.

The occurrence of hail does not necessarily result in serious damage to crops, as the fall may be only of small amount, doing no harm. This fact should be borne in mind when considering the greater number of these storms over the western Plains and central Rocky Mountain region, as compared with other portions of the country. Hailstorms are often extremely local in character; great damage may be done on a single farm while others adjoining may escape unharmed.

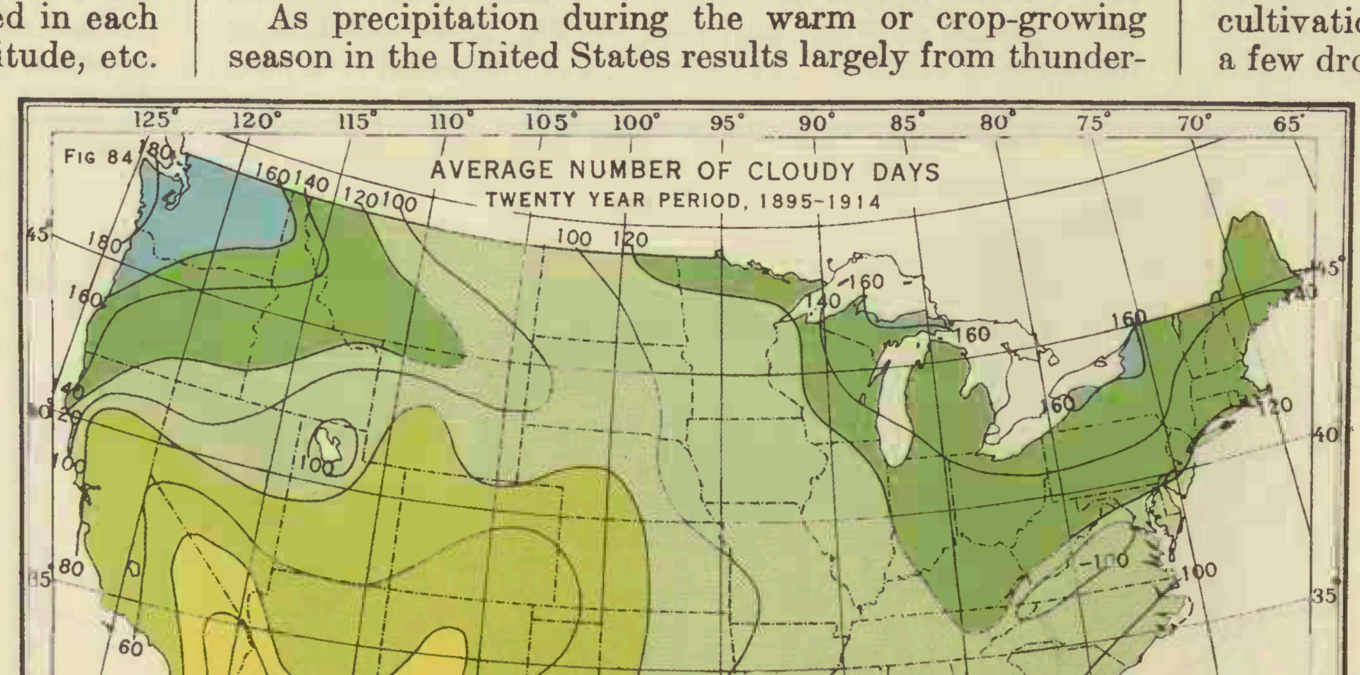


Figure 84.—This chart shows the average annual number of cloudy days. In extreme upper Michigan there are on the average about 160 cloudy days during the year and along the extreme North Pacific Coast about 180 days are cloudy. The fewest number of cloudy days are found in southwestern Arizona and the southeastern portion of California, where, as a rule, fewer than 20 days of the year are cloudy. Partly cloudy days, as classified by the observers of the Weather Bureau, are not included in this chart.

FOG.

Two degrees of fogginess are recognized by the Weather Bureau and recorded at all full reporting stations, namely, "light" and "dense." Fog sufficiently dense to obscure objects at a distance of 1,000 feet from the observer is recorded as "dense," otherwise as "light."

Figure 82 shows for the different portions of the country the average annual number of days with dense fog, based on records of all full reporting Weather Bureau stations for the 20-year period 1895–1914. The regions of greatest fog frequency are found along the Pacific and North Atlantic coasts, over the central and southern portions of the Appalachian Mountain region and along the western Gulf Coast. The region of least frequency comprises the districts between the Rocky Mountains and the Pacific Coast States, where, as a rule, there are fewer than five foggy days during the year. Fog generally is of infrequent occurrence throughout the interior portion of the country, most of those districts having on the average fewer than 10 days with dense fog during the entire year. The occurrence of fog is not of special agricultural significance, although it sometimes contributes appreciable moisture to plants during dry periods, especially on the Pacific Coast.

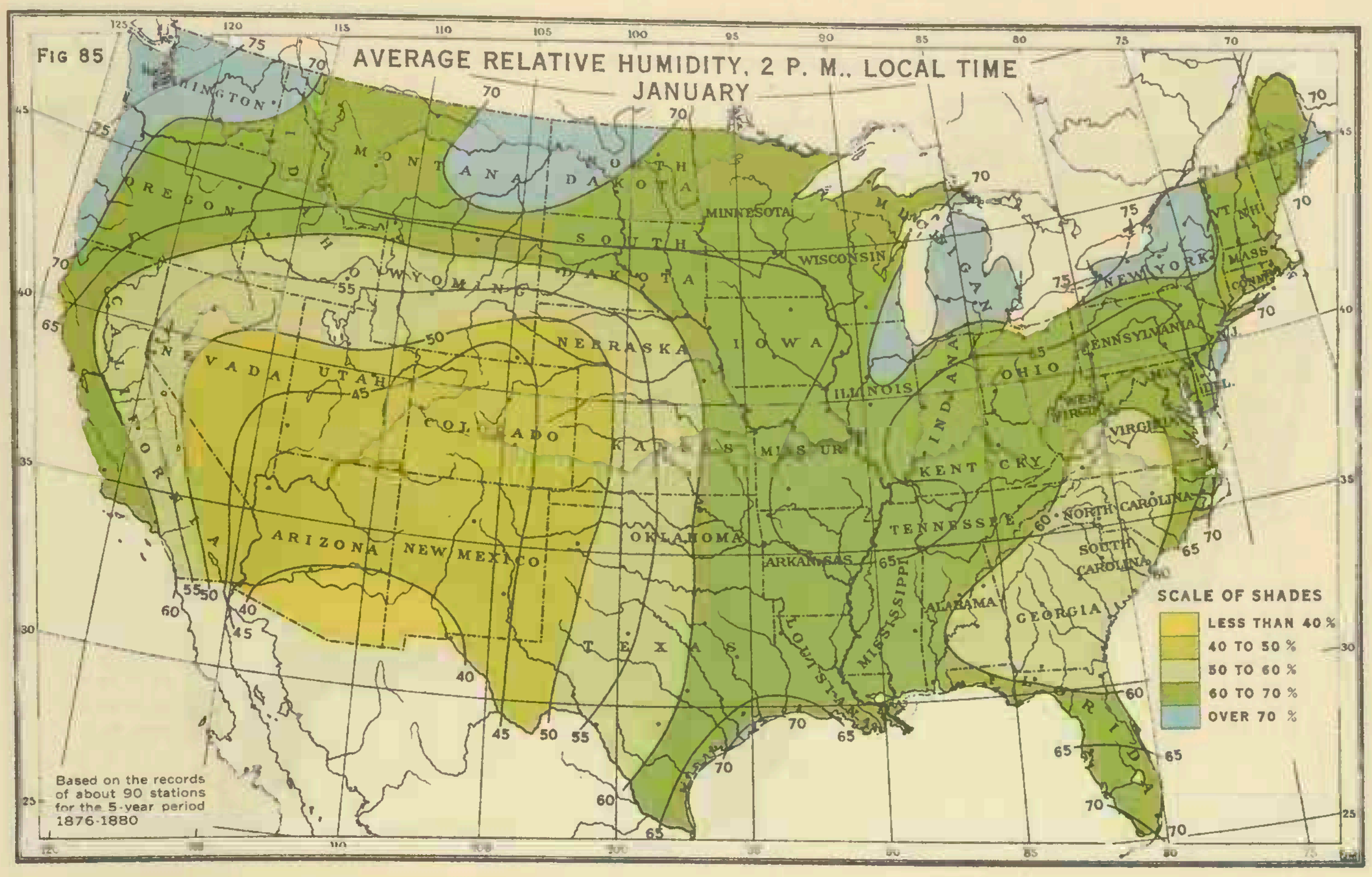
THUNDERSTORMS.

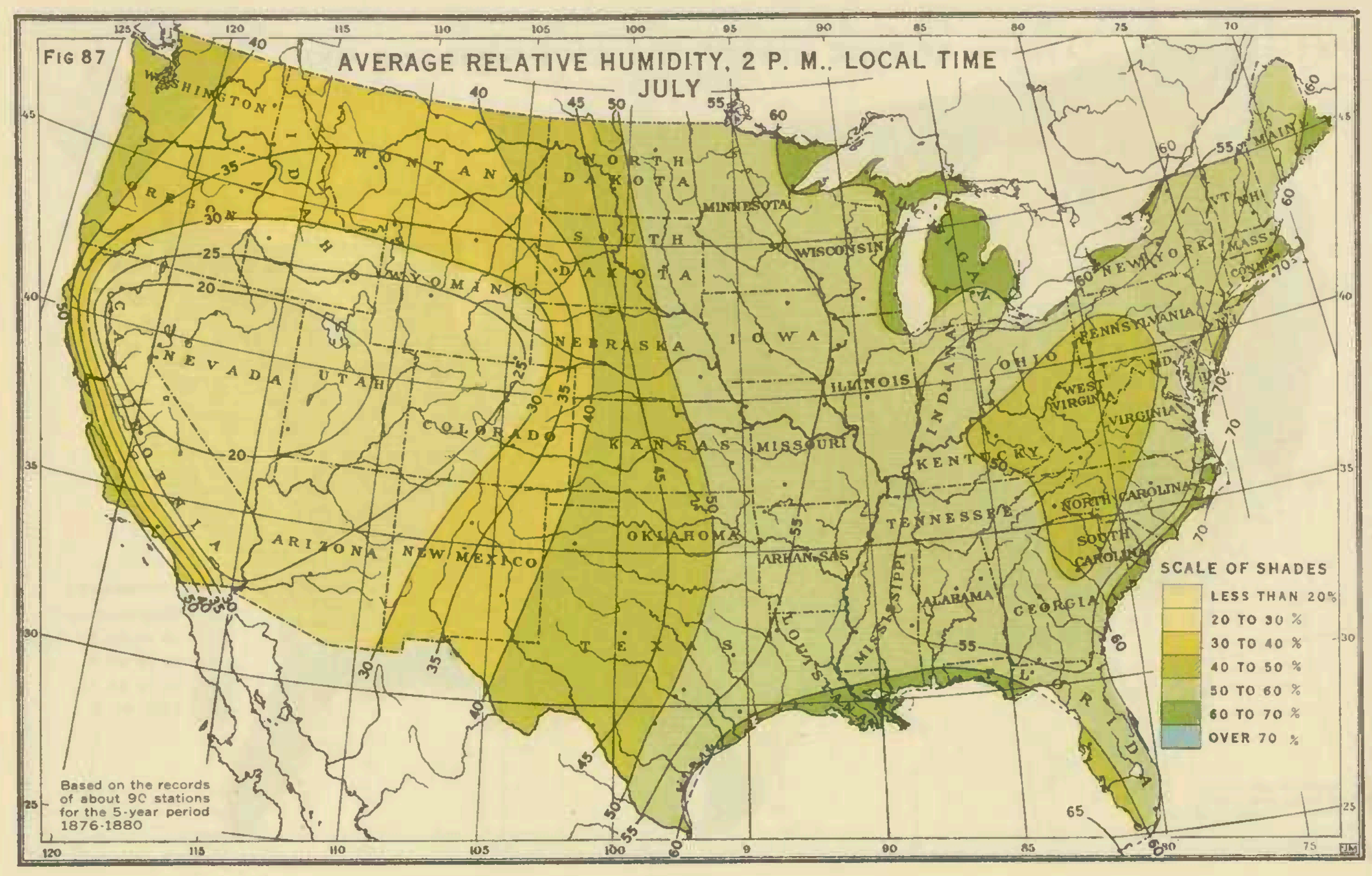
As precipitation during the warm or crop-growing season in the United States results largely from thunderstorms, these local atmospheric disturbances are of great importance agriculturally. They are caused by atmospheric convection, or a vertical interchange of air masses of different temperatures and humidities. There are two recognized classes of thunderstorms, which have been designated "heat" thunderstorms and "cyclonic" thunderstorms. Those of the first-named class usually develop on hot summer afternoons in regions of weak barometric gradient and moist, quiet air; while those belonging to the other class occur under the influence of cyclonic storms, more frequently in the southeast quadrant of the low-pressure area. The breaking up of a long heated period is frequently attended by thunderstorms of rather marked severity which are more or less connected with cyclonic action, as the breaking-up process is usually accomplished by a cyclonic wind movement relieving the stagnant air condition.

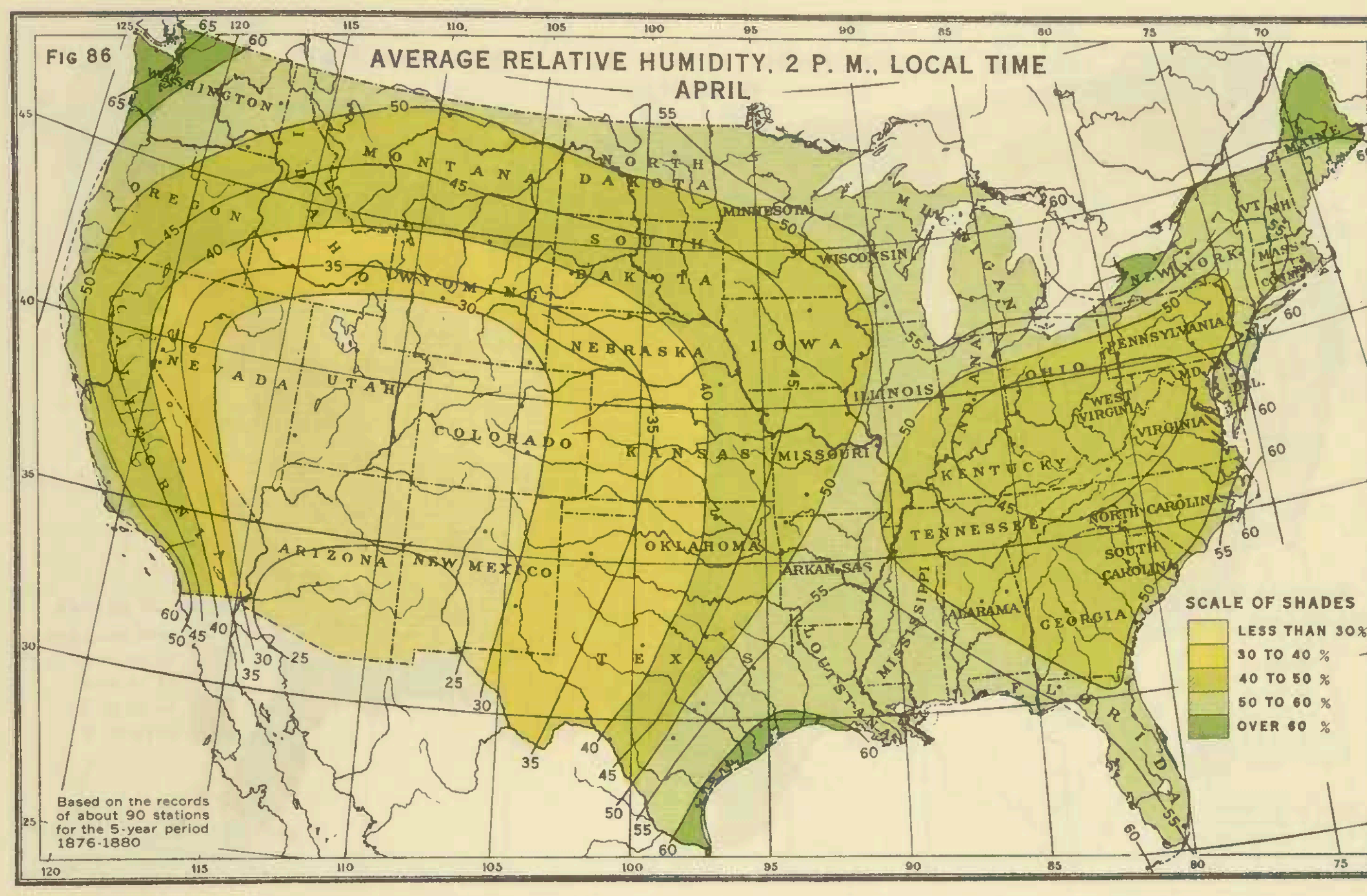
Thunderstorms and the resulting precipitation are often extremely local in character, especially in the summer season. Occasionally in a single small field rainfall may occur in one portion sufficient to delay cultivation temporarily, while in another portion only a few drops fall. Thunderstorms are sometimes severe in character and accompanied by destructive wind and hail. The area of destruction is usually not extensive for an individual storm, but several may occur in quick succession on the same day. Excessive rainfall during short periods of time is often the result of thunderstorm activity, particularly during the summer season.

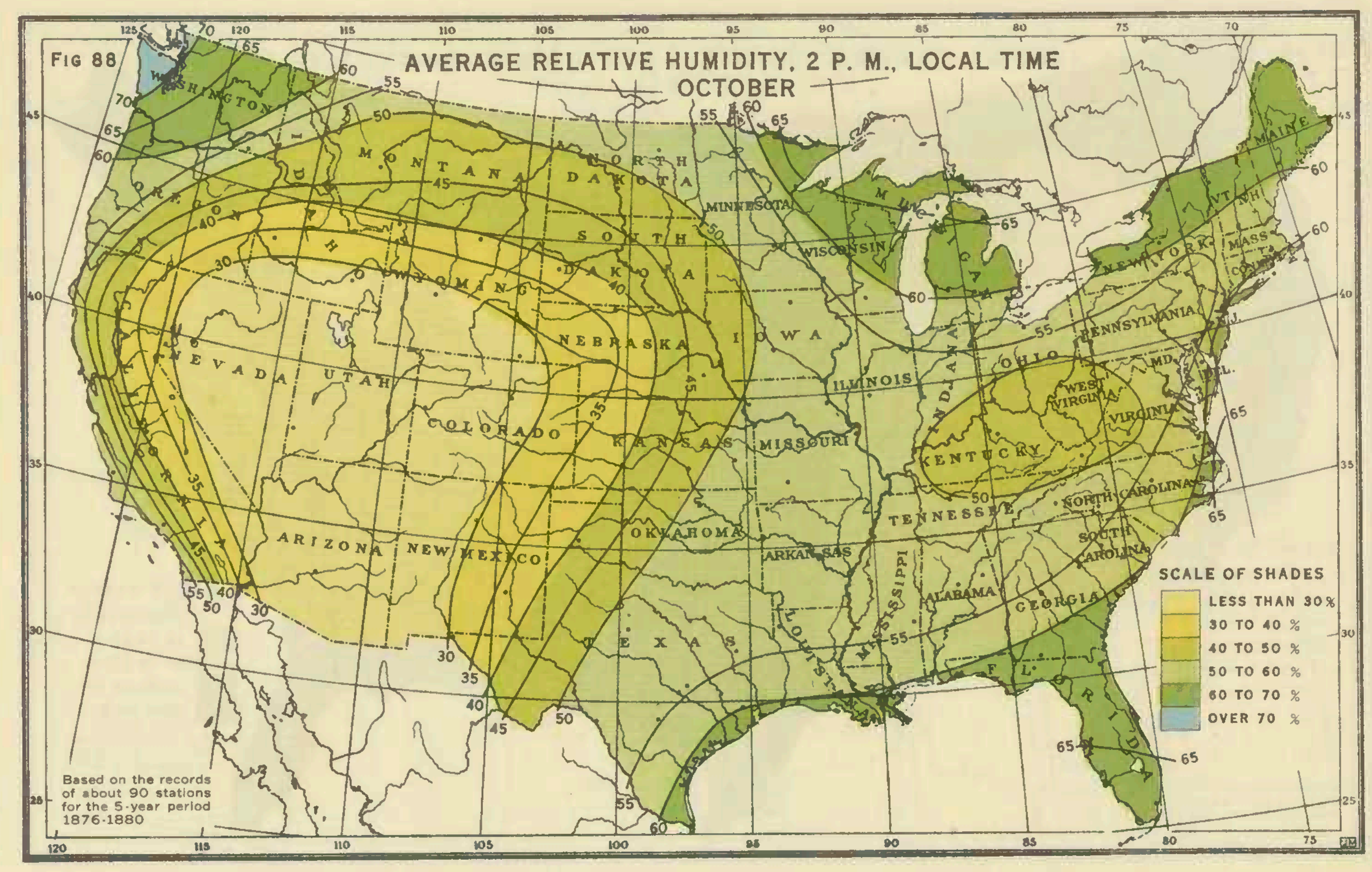
Figure 81 shows the average annual number of days with thunderstorms for the different sections of the United States, based on the records of all regular reporting Weather Bureau stations, about 200 in number, for the 10-year period 1904–1913. It will be noted from this chart that the region of greatest frequency is to be found along the central and eastern Gulf Coast, where thunderstorms occur on 80 to 90 days annually, and that the smallest number is in the Pacific Coast States, where, as a rule, they are recorded on from two to four days a year only.

The month of fewest thunderstorms is January, when, as a rule, they occur on one or two days only in the region of their greatest frequency, which comprises the Gulf States. July and August have the greatest number the area of maximum frequency for these months being along the eastern Gulf Coast, where they occur in each month on an average of about 20 days. Thunderstorms are frequent during these two months also in the far Southwest, resulting in the Arizona type of precipitation.









Figures 85 to 88 show the average relative humidity, in percentages of saturation, at 2 p. m. local time, for the months of January, April, July, and October. These charts are based on the records of about 90 stations for the 5 years 1876 to 1880, inclusive, during which time humidity observations were made regularly at all of the then full-reporting stations of the Weather Bureau. These records embrace the only extensive relative humidity data that have been made at the same hour of local time throughout the country, and are thereby comparable for the different sections. However, the period covered is comparatively short and the psychrometric tables employed in reducing the observations, as well as the manner of observing the instruments, have since been revised, which render the data not directly comparable with averages for longer periods and for more recent years. The average minimum relative humidity for the 24-hour period does not differ greatly from the average at 2 p. m., except that in most seasons of the year the minimum relative humidity usually occurs a little later than this hour and is a little lower. For some purposes, therefore, figures 99, 100, and 101, which are based on more recent and extensive data, may preferably be used instead of the maps above.

HUMIDITY.

THE humidity of the atmosphere is of great climatic importance, not only from the standpoint of its influence on bodily comfort, but also because of its direct relation to plant life and its bearing on commercial and other activities. In discussing atmospheric moisture four terms are in common use—"absolute humidity," "relative humidity," "the temperature of the dew point," and "depression of the wet-bulb temperature." Absolute humidity is the actual amount of moisture in the atmosphere, usually expressed in inches of barometric pressure, in this case called "vapor pressure," but sometimes it is given as the actual weight of moisture present in a unit volume of air. By relative humidity is meant the ratio the amount of moisture present in the atmosphere bears to the amount that could exist without condensation under the same conditions of temperature and atmospheric pressure. The dew point is the temperature at which saturation occurs and the condensation of the invisible aqueous vapor begins. The depression of the wet-bulb temperature is the difference in temperature registered by a thermometer whose bulb is covered with saturated gauze or other freely evaporating surface and that registered by an adjacent ordinary dry-bulb thermometer. The amount of this depression varies inversely with the relative humidity, provided the temperature remains unchanged.

FIGURE 89

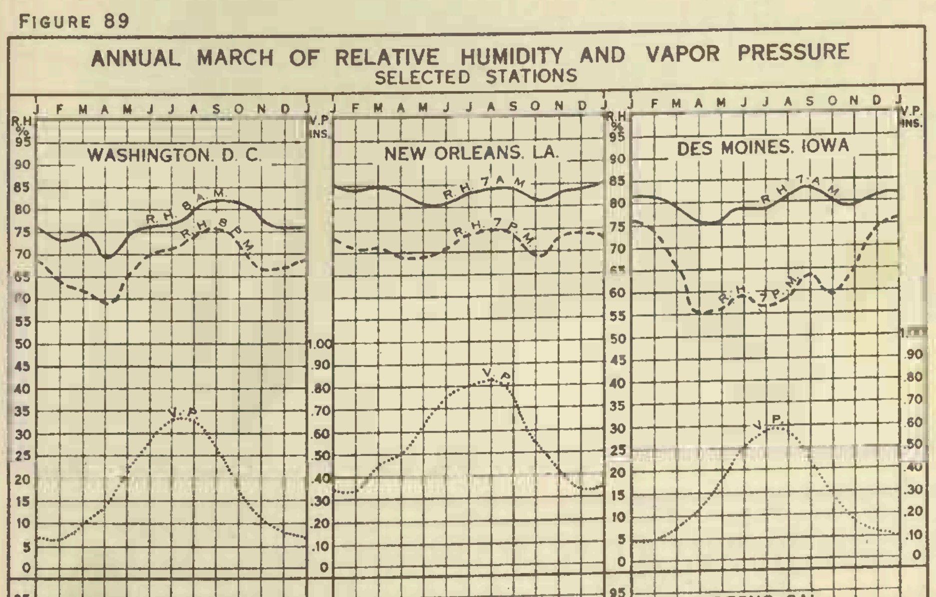


Figure 89 shows for selected stations the annual march of relative humidity and vapor pressure. The relative humidity values for the several months represent averages for each of the regular 8 a. m. and 8 p. m., 75th meridian time observations, with the hour of local standard time at which they were made indicated on each curve. The vapor pressure curves are based on observations made at 8 a. m., 75th meridian time, but these do not differ much from the daily averages, as the diurnal variations in vapor pressure are usually small. The relative humidity values are given in percentages of saturation and the aqueous vapor in inches of barometric pressure.

Absolute Humidity.—The actual amount of moisture in the atmosphere depends upon the temperature, and to a less extent upon the location with respect to large bodies of water, the latter being the principal source of supply. The diurnal fluctuations are comparatively small and are due largely to the varying rate, from day to night, of evaporation from moist surfaces and to condensation; i. e., precipitation, dew, etc. The maximum, consequently, usually occurs during the day and the minimum during the night.

The seasonal variations in absolute humidity are large, there being usually from two to four times as much moisture in the atmosphere in midsummer as in midwinter. Figure 89 shows for selected stations the annual march of absolute humidity as measured by vapor pressure, and figures 102 and 106 show the average vapor pressures in different portions of the United States for January and for July. The seasonal curve of vapor pressure follows closely the trend of that of temperature.

Relative Humidity.—The absolute humidity in the atmosphere is not so important climatically as the relative amount, since it is the latter that determines whether the climate of a place is physically moist or dry (with reference to its general temperature conditions). Climates recognized as dry are not necessarily deficient in actual atmospheric moisture since even in a desert the absolute humidity may equal or exceed that in a climate usually considered as moist. Figure 106 shows that in southwestern Arizona, commonly referred to as one of the driest localities in the United States, there is in July more moisture in the atmosphere than at points on the Great Lakes, where the climate is considered moist. The physical effect of the moisture condition of a locality is much more clearly indicated, therefore, by the relative humidity than by the actual amount of aqueous vapor present in the atmosphere.

Depression of the Wet-Bulb Temperature.—The depression of the wet-bulb temperature varies inversely with the relative dryness of the atmosphere, provided there is no change in temperature. Charts 103, 104, and 105 show for the months of April, July, and October the computed average daily depression of the wet-bulb temperature at the time of minimum relative humidity, which corresponds to the time of maximum temperature. Owing to the large depression of the wet-bulb in the far Southwest the high summer temperatures experienced are not so oppressive as appears to be indicated by the dry-bulb thermometer readings alone, since the dryness of the atmosphere increases the opportunity for evaporation and thus reduces the sensible temperature.

FIGURE 90

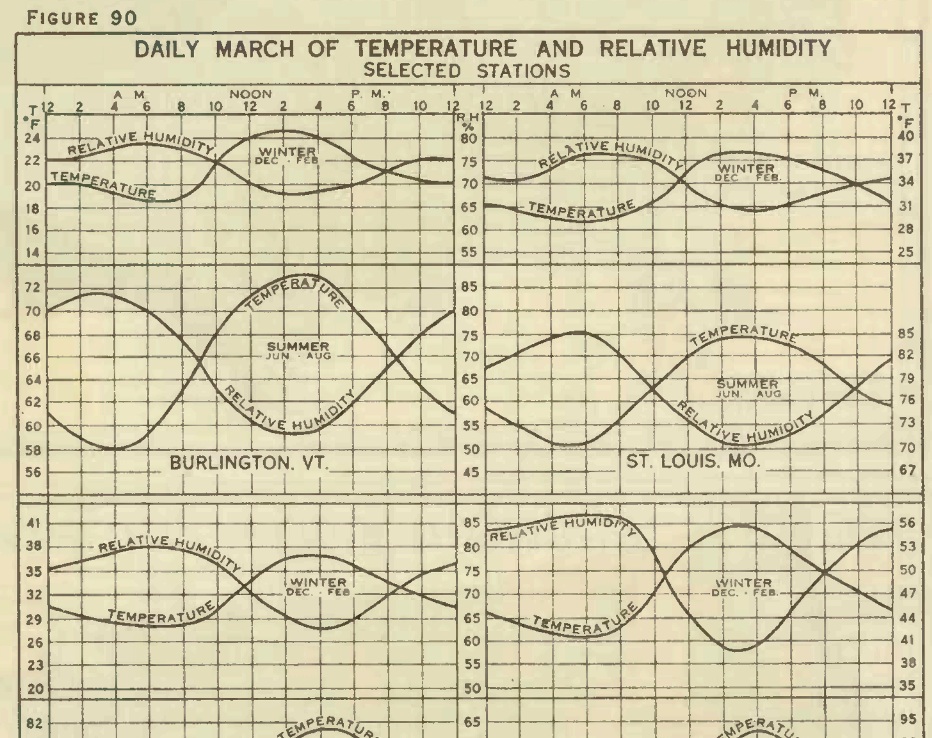
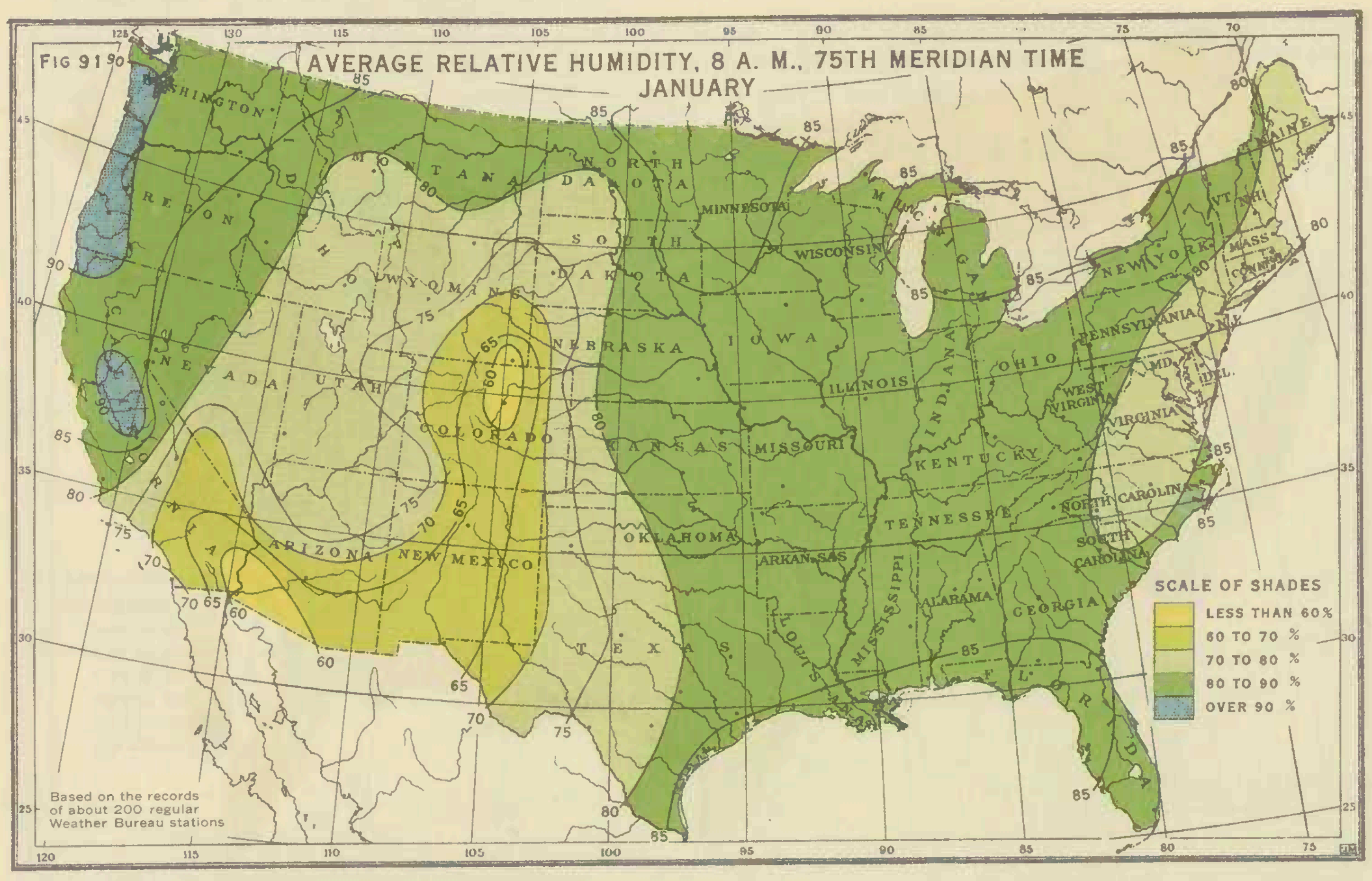
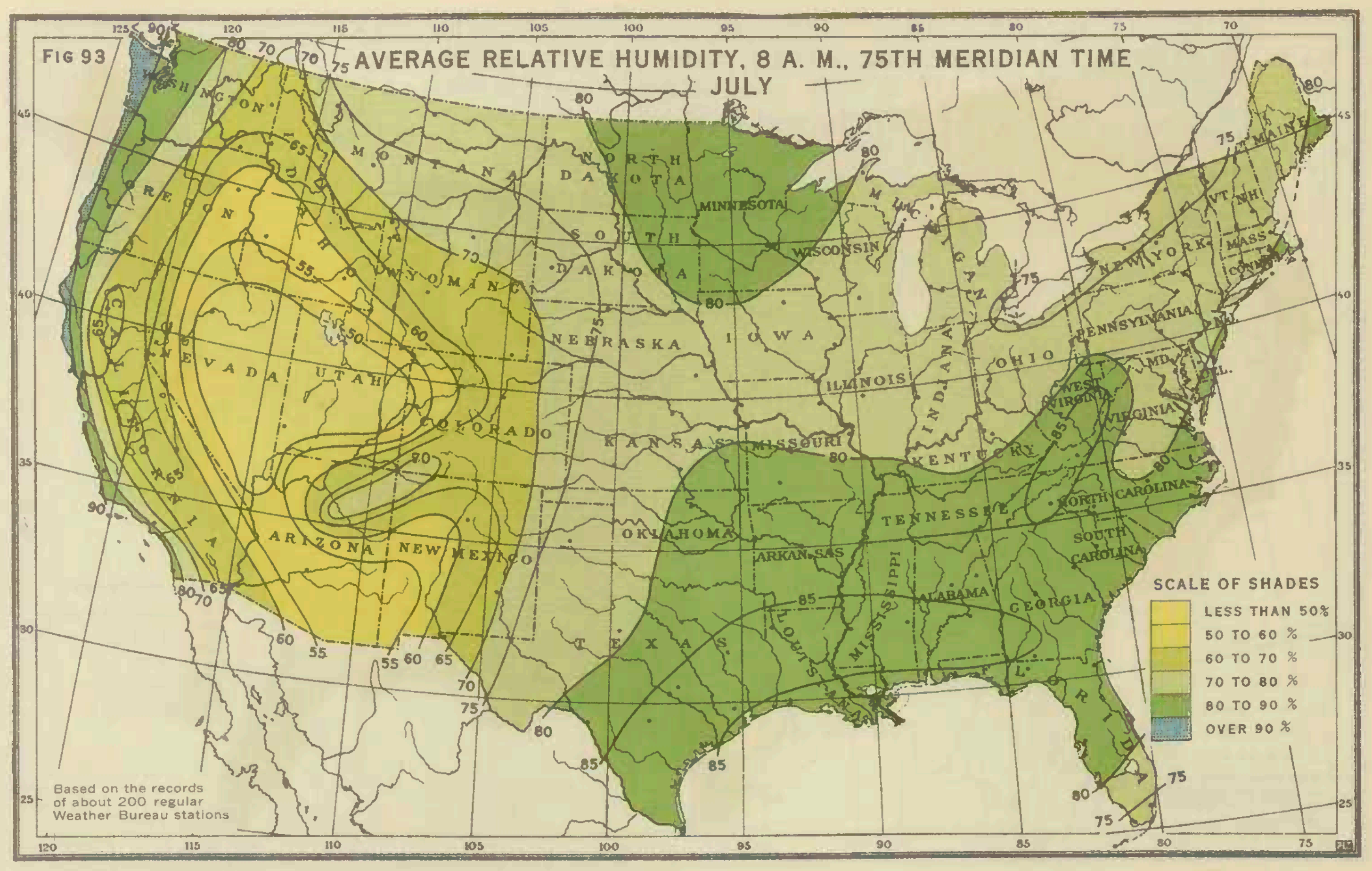
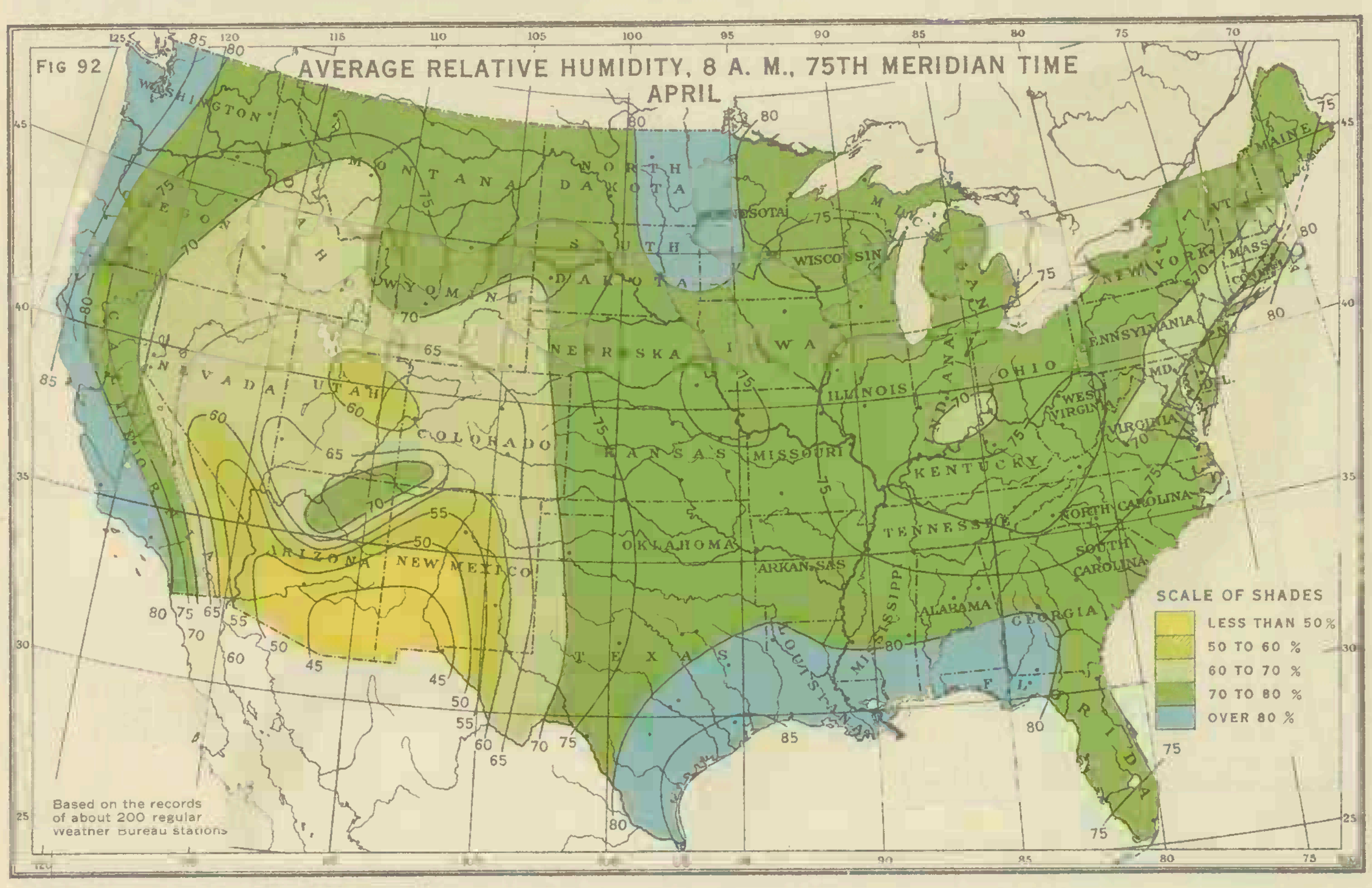
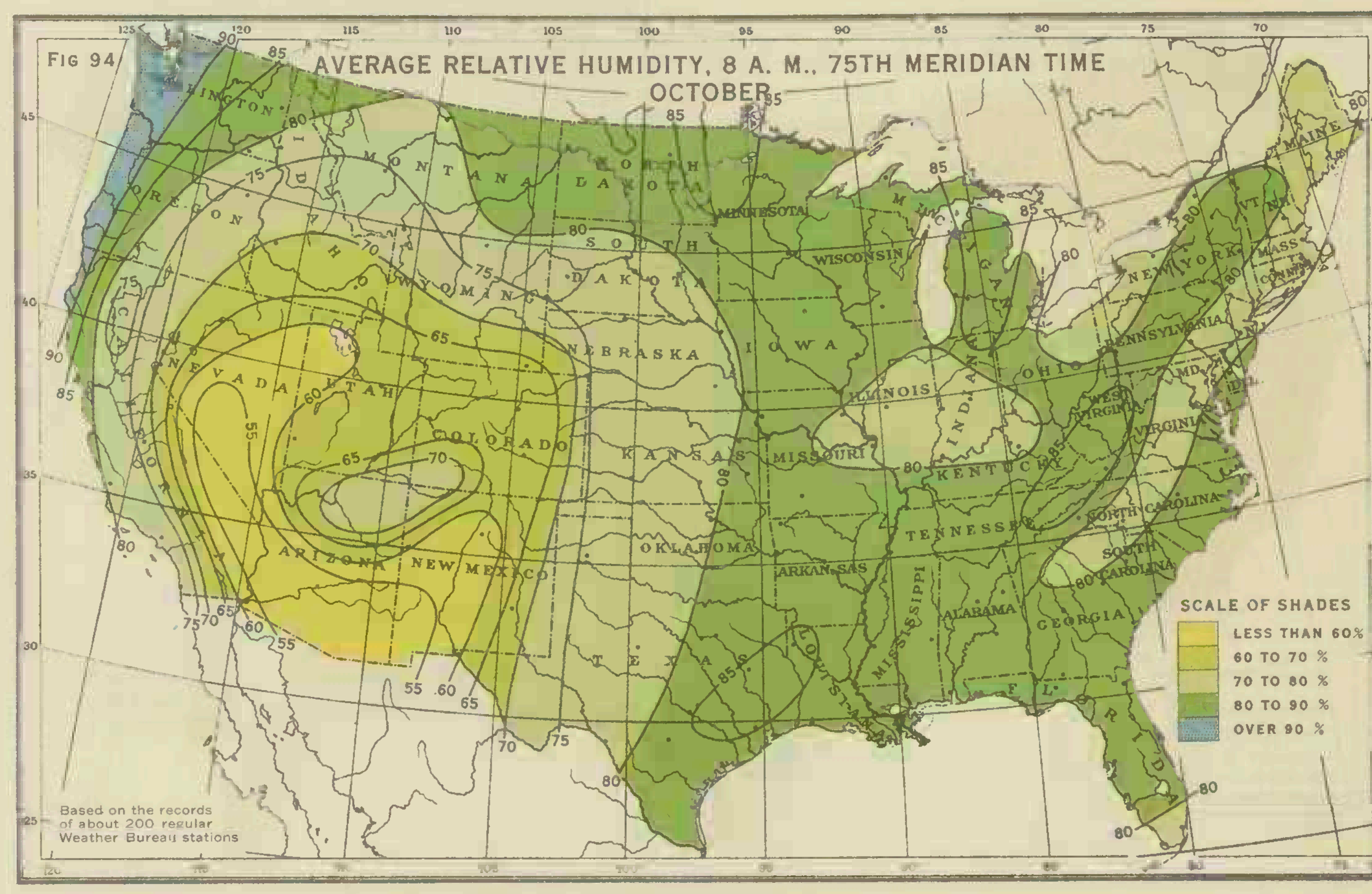


Figure 90 shows for selected stations the diurnal march of relative humidity and temperature. The diurnal march of relative humidity is pronounced and corresponds closely, but inversely, to the daily temperature curve. For each change of 1 degree in temperature there is, on the average, a corresponding change, but in an opposite direction, of from 1.5 to somewhat more than 2 per cent in relative humidity, depending upon the locality. The maximum relative humidity of the day occurs usually near the time of sunrise and the minimum from two to four hours after noon, or the reverse of the hours of occurrence of the maximum and minimum temperatures.

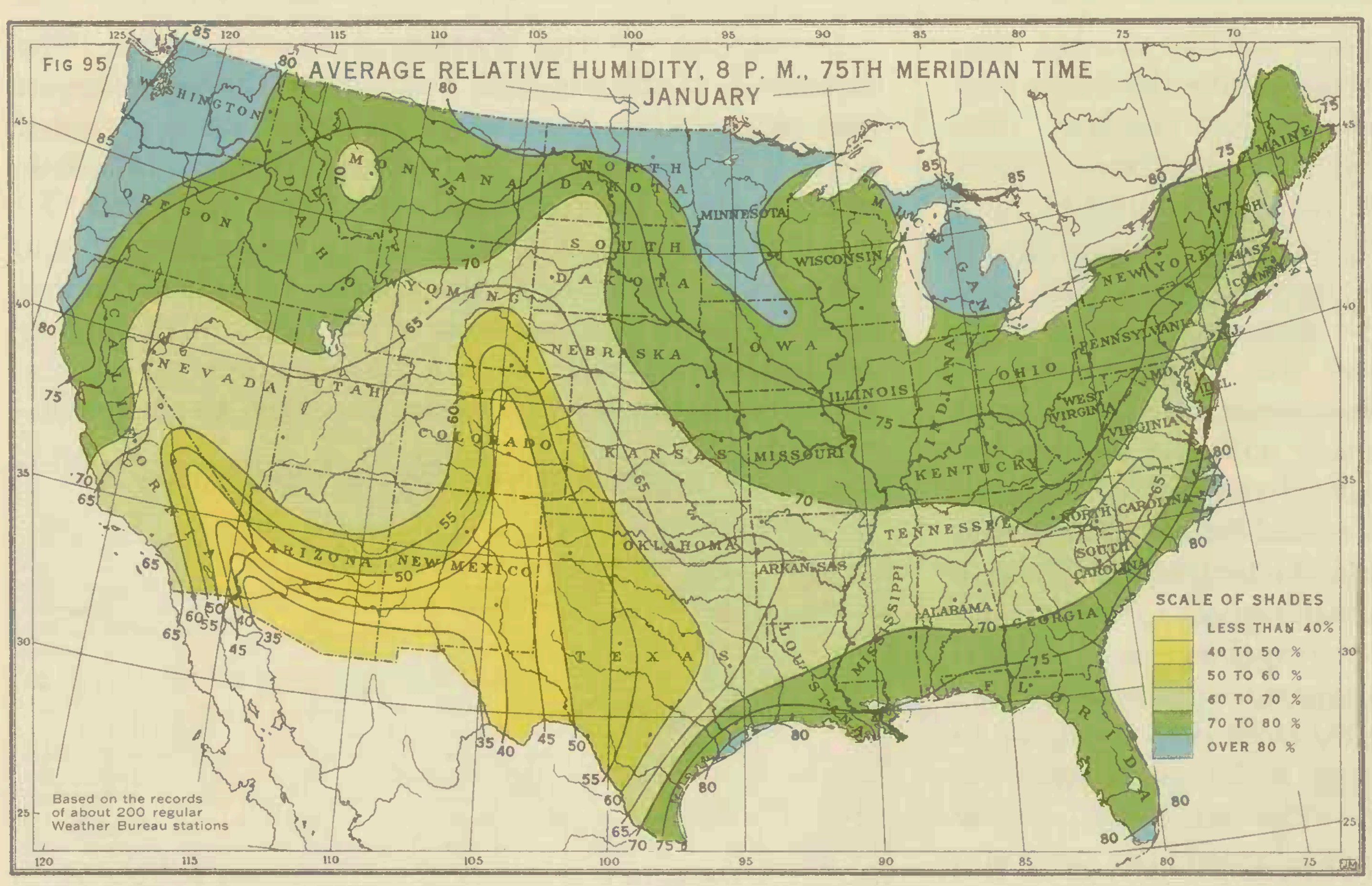


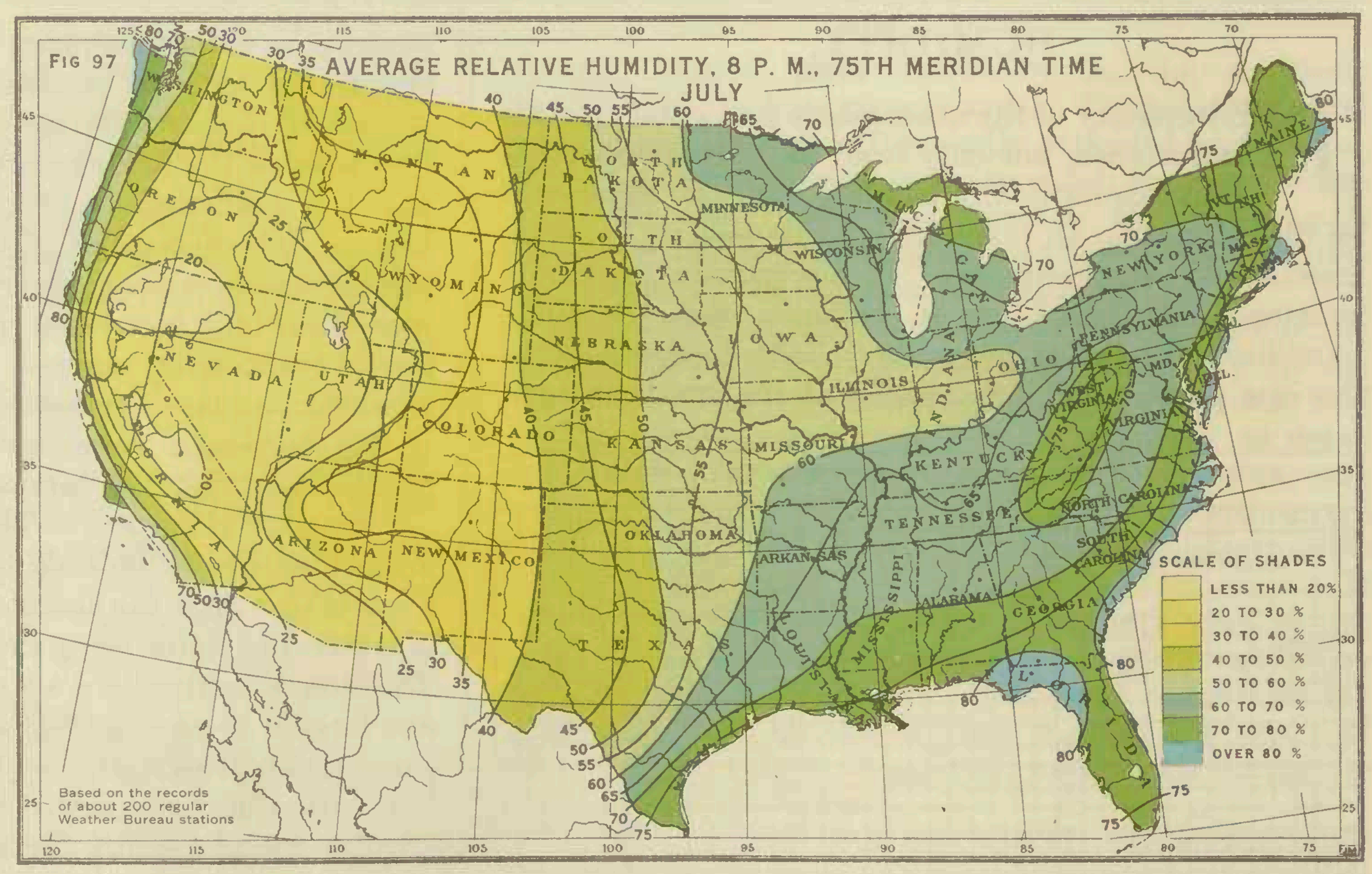


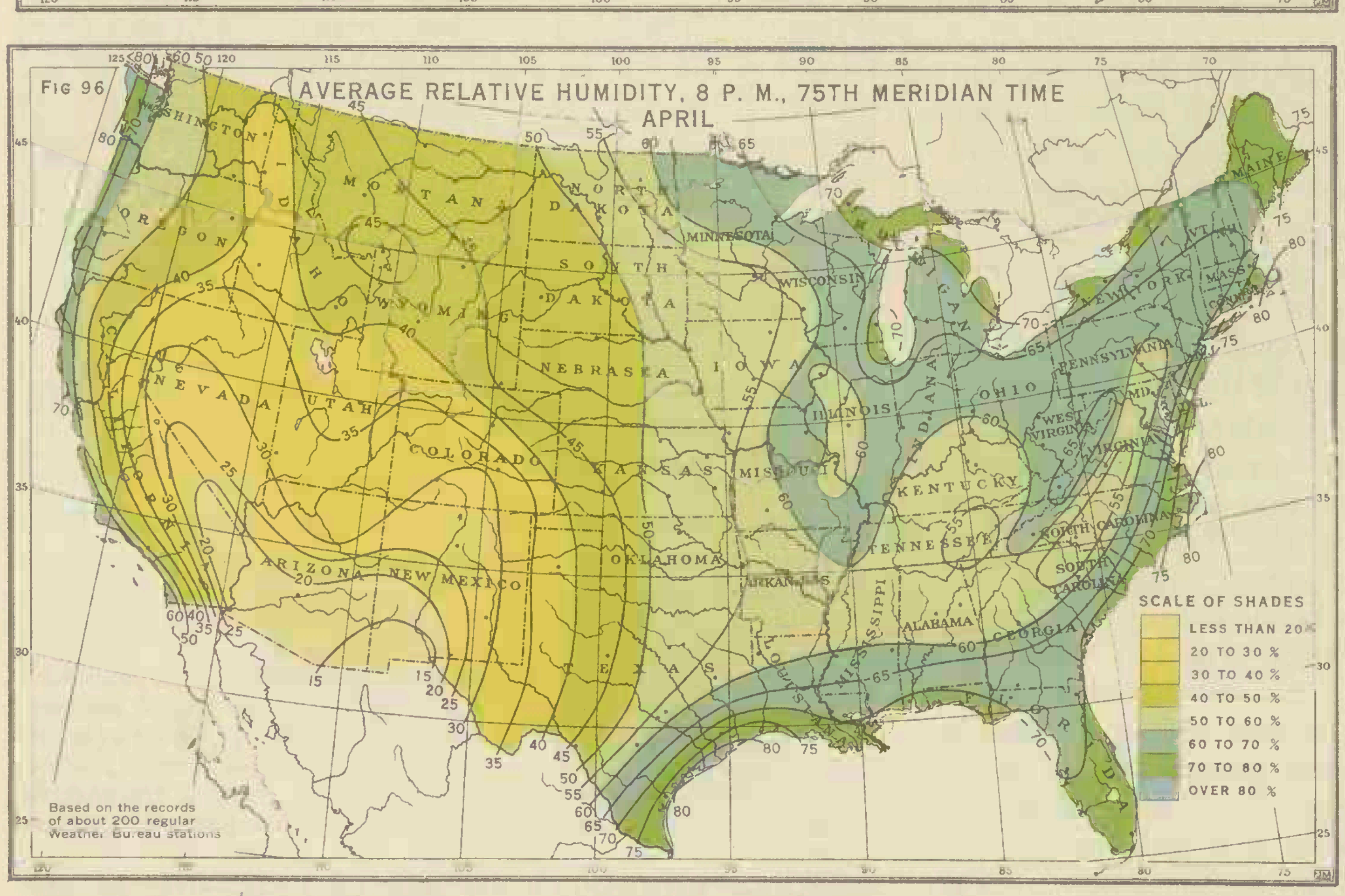


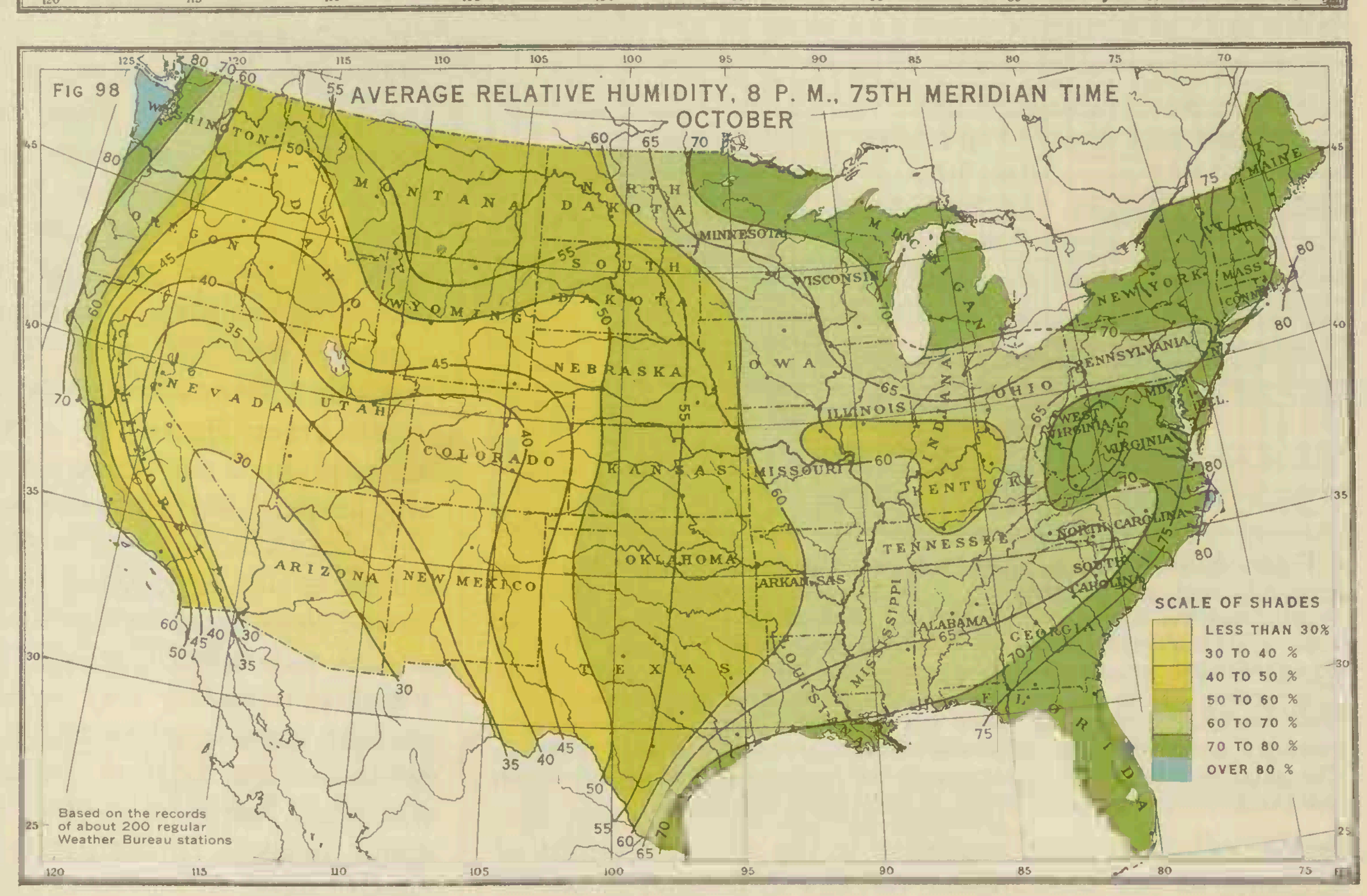


Figures 91 to 94 show for the mid-season months, January, April, July, and October, the average relative humidity at 8 a. m., 75th meridian time, for the 25-year period 1888–1913. These data, and the corresponding data for 8 p. m., figures 95 to 98, are the most extensive observations of relative humidity made by the Weather Bureau, but are not strictly comparable for different sections of the country, owing to the difference in local time at which the observations were made at the various stations, being three hours earlier in the day in the extreme West than in the extreme East. The 75th meridian passes nearly through Philadelphia, and the observations are taken at 8 a. m. standard time in the Eastern time belt, 7 a. m. in the Central time belt, 6 a. m. in the Mountain time belt, and 5 a. m. in the Pacific time belt. The values for the 8 a. m. observations are considerably higher than the daily averages and those for the 8 p. m. are appreciably lower, the departures from the daily mean becoming increasingly greater with progress westward, due to the earlier local time. West of the Rocky Mountains the 8 a. m. values approach the maximum for the day and the 8 p. m. are near the minimum, the averages of the two observations representing in these districts very nearly the 24-hour mean.

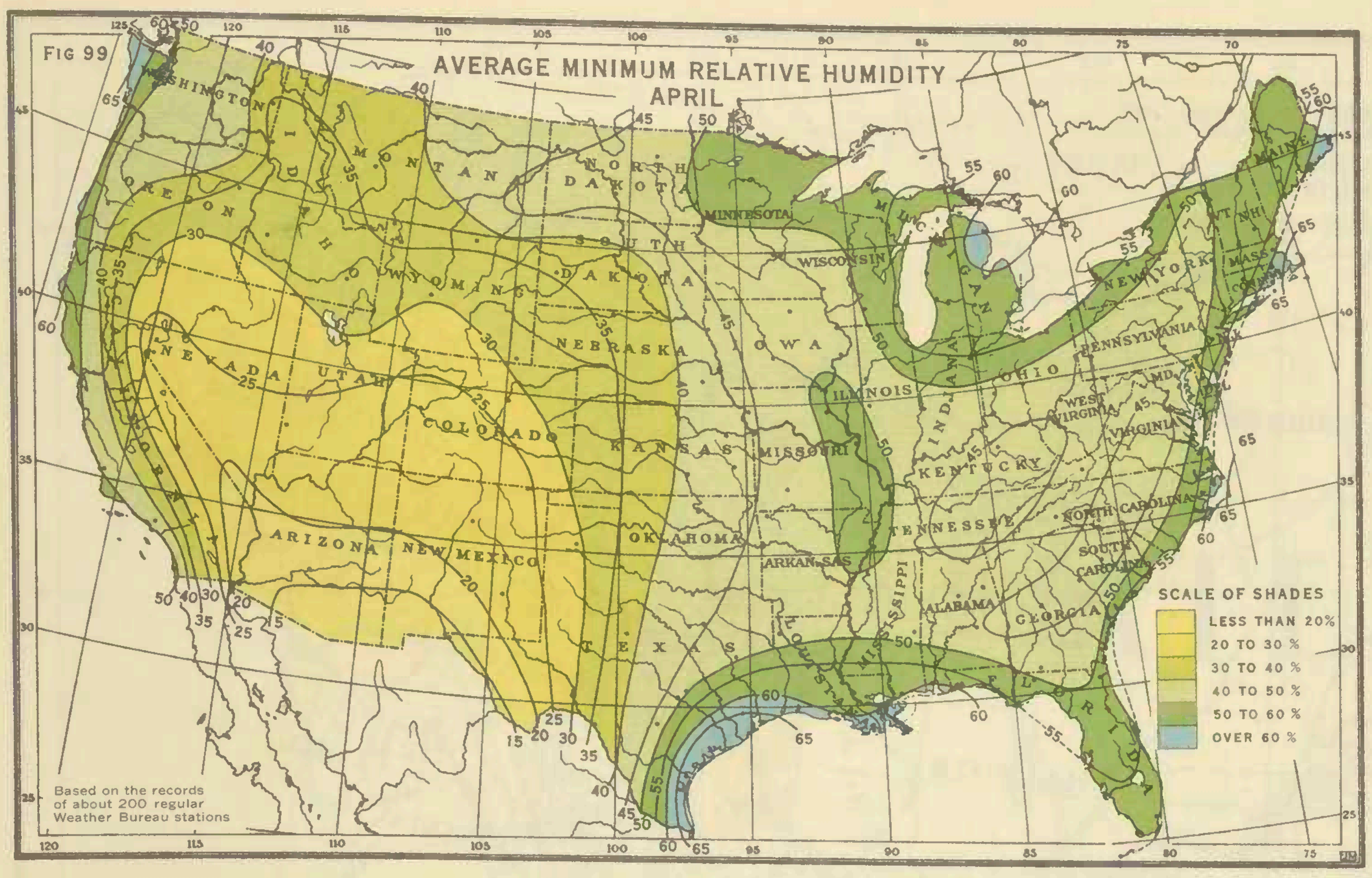


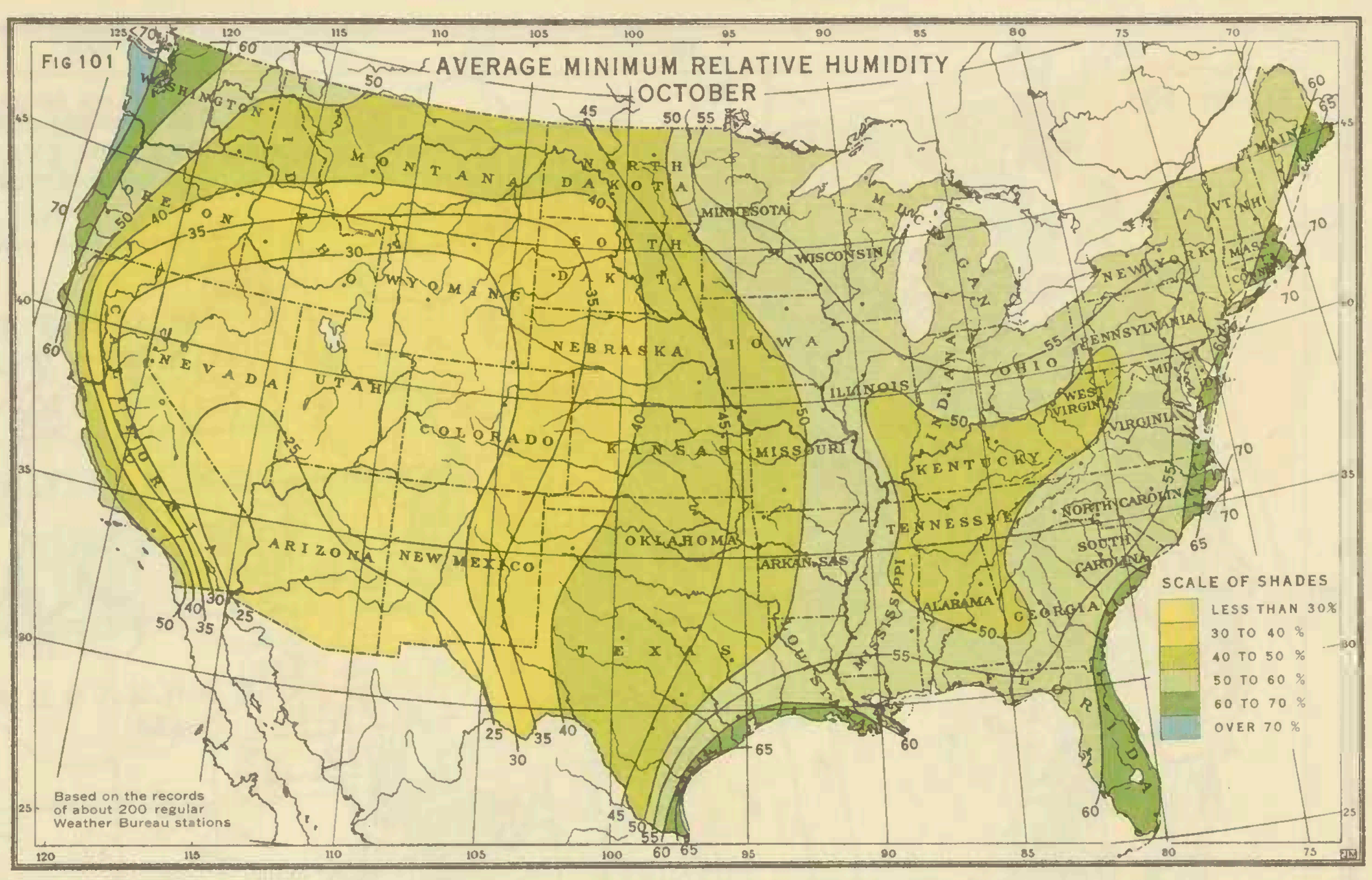


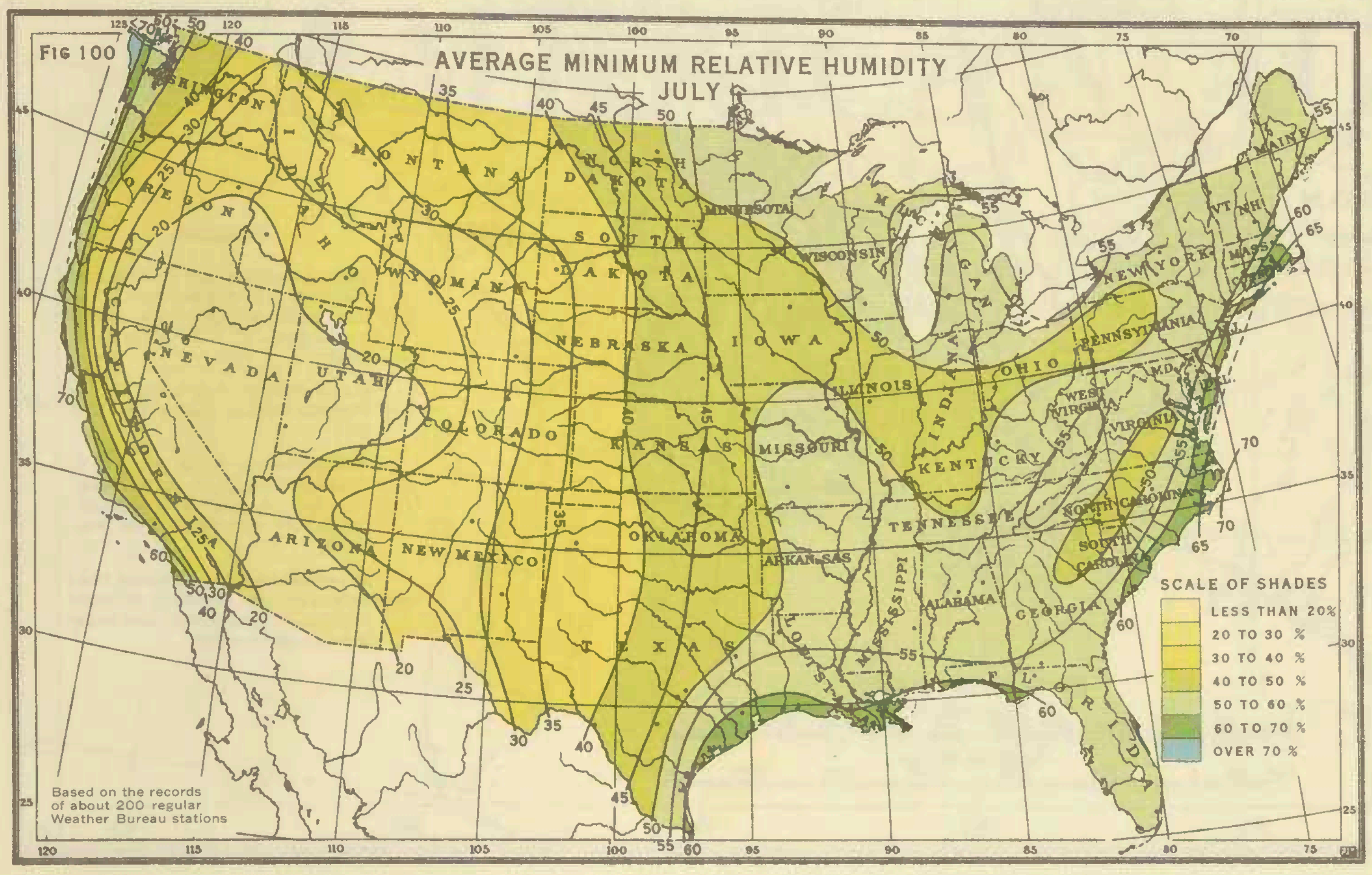


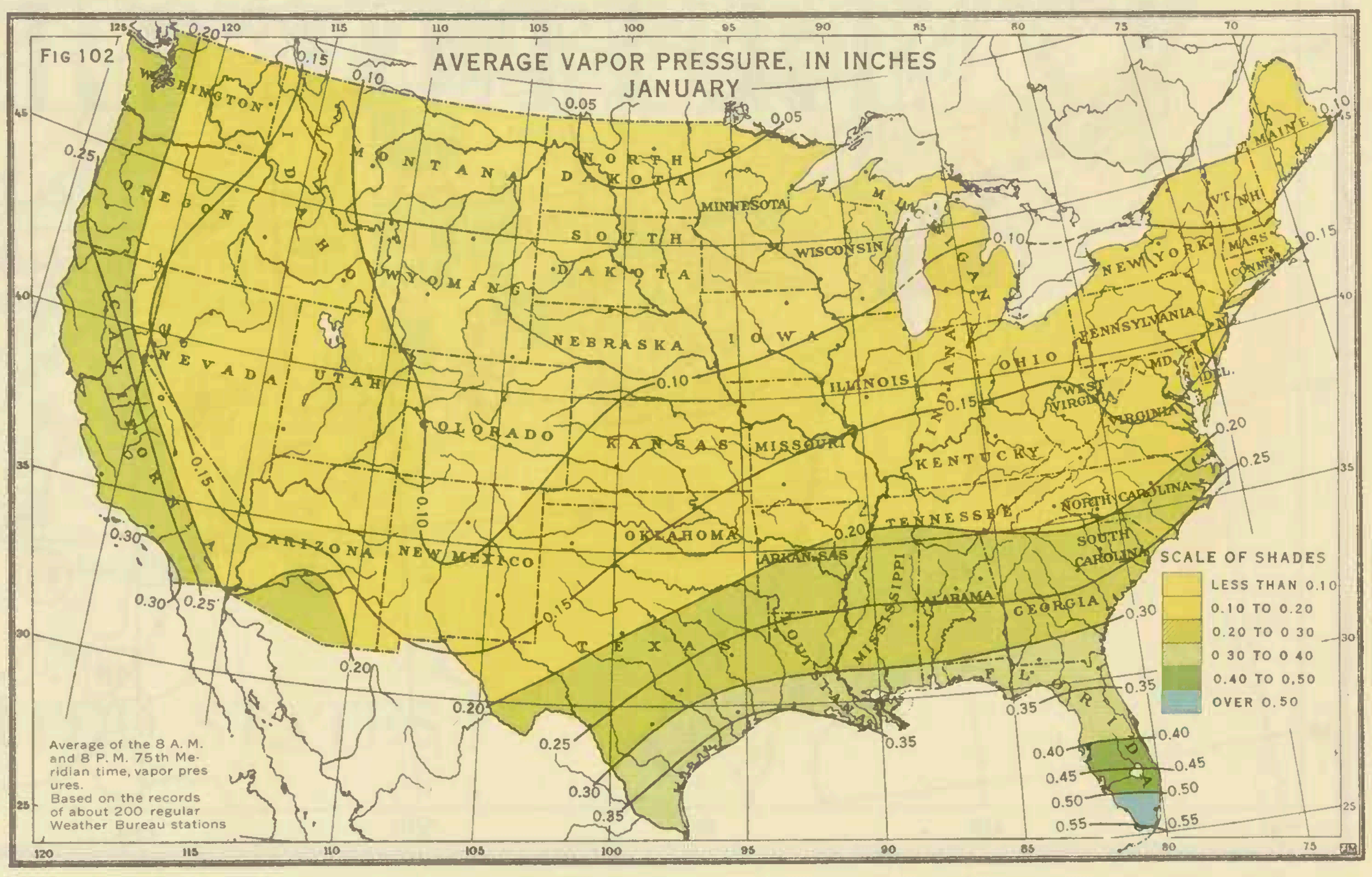


Figures 95 to 98 show the average relative humidity at 8 p. m., 75th meridian time, in January, April, July, and October. The seasonal variations in relative humidity follow no definite law, but in general for districts east of the Rocky Mountains the atmosphere is relatively driest in the spring, in April as a rule, while to the westward the lowest relative humidity occurs in midsummer. The highest relative humidity occurs usually in winter, except in the Southeastern States, where the maximum frequently occurs in the late summer or early fall. Geographically, the lowest relative humidity is found at all seasons of the year in the far Southwestern States, and the highest along the North Pacific Coast and in other regions contiguous to large bodies of water, especially those located on the leeward side. In most elevated regions the relative humidity is also comparatively high, with small diurnal and seasonal variations.

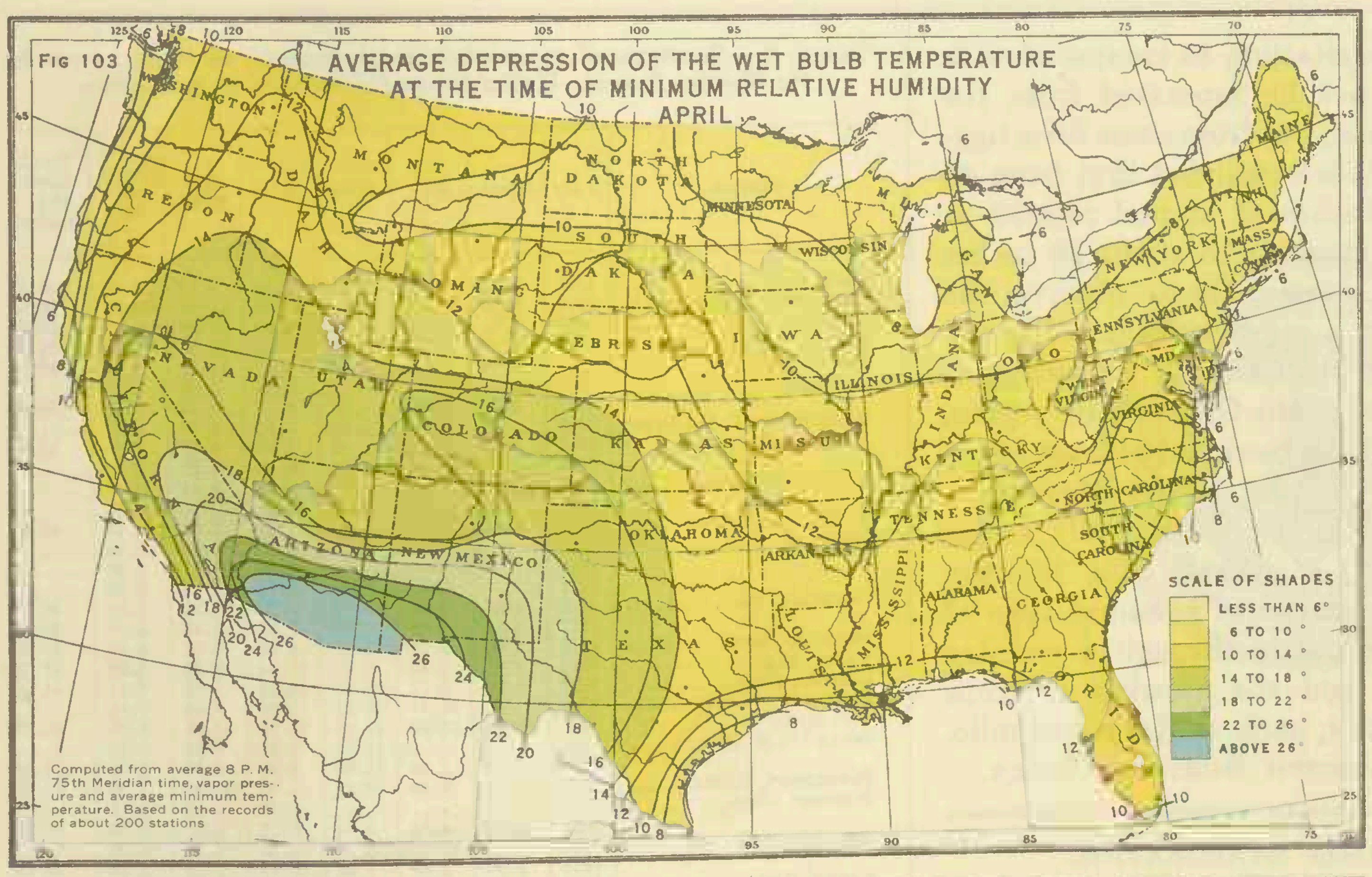


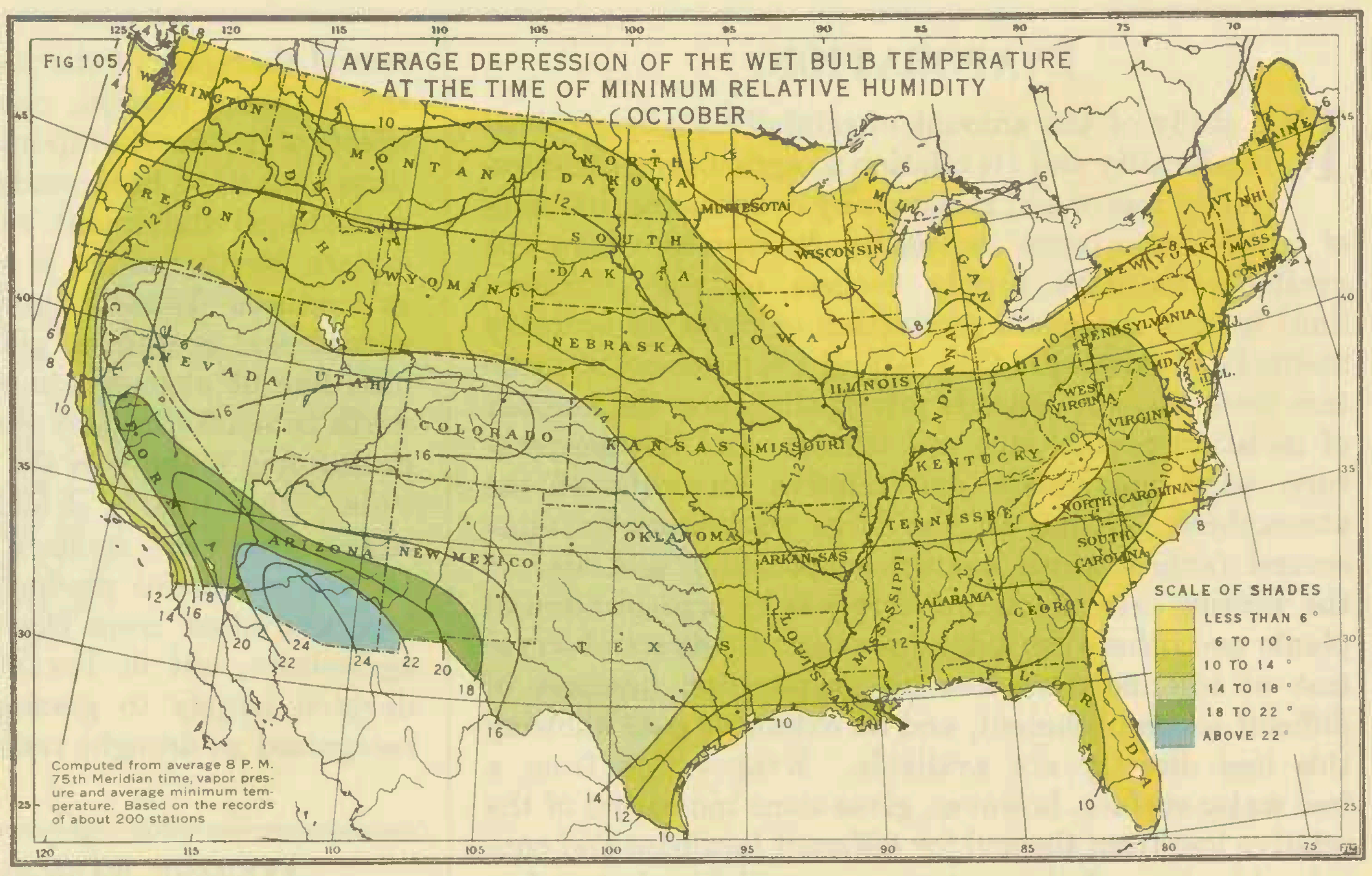


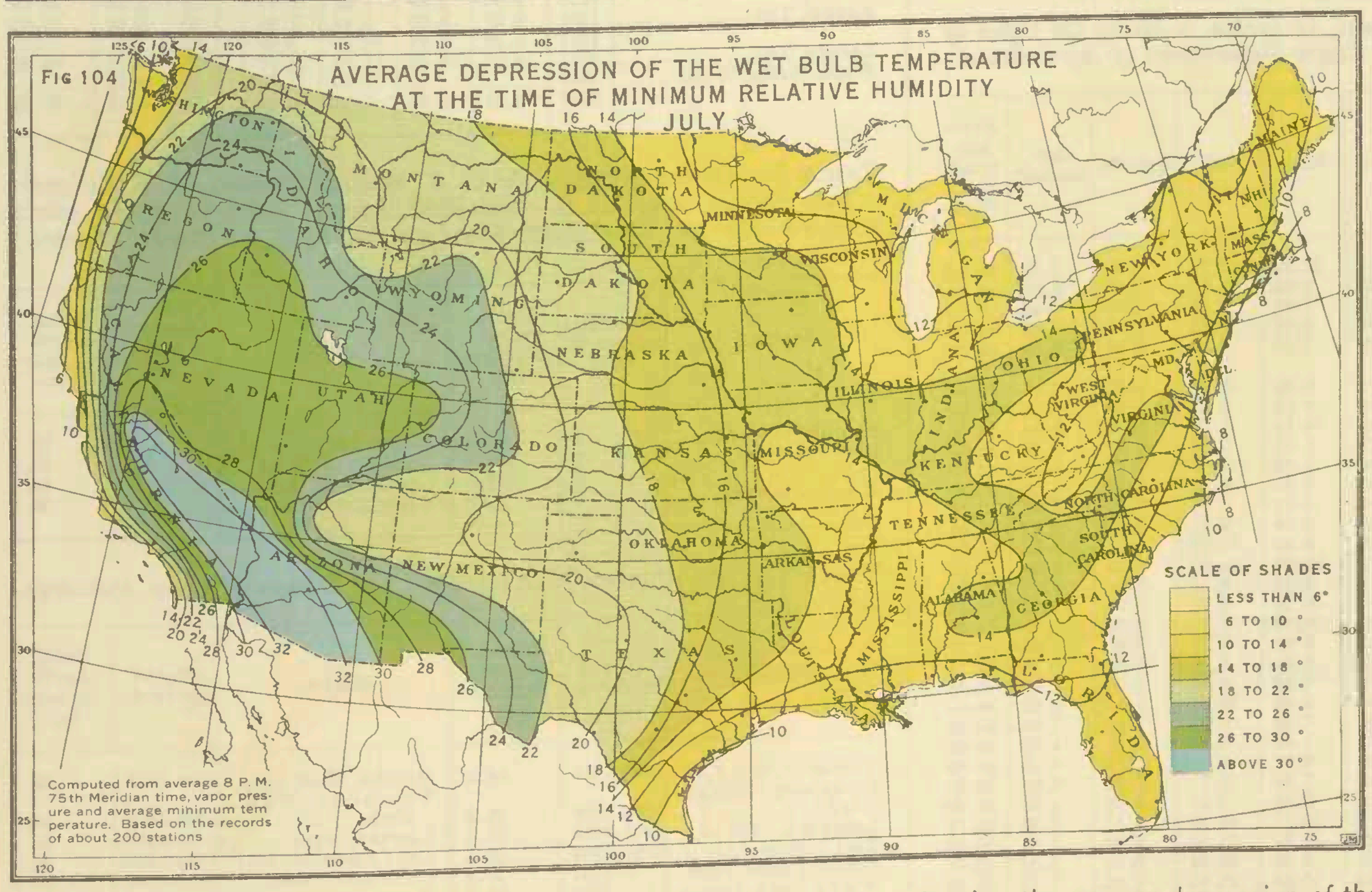


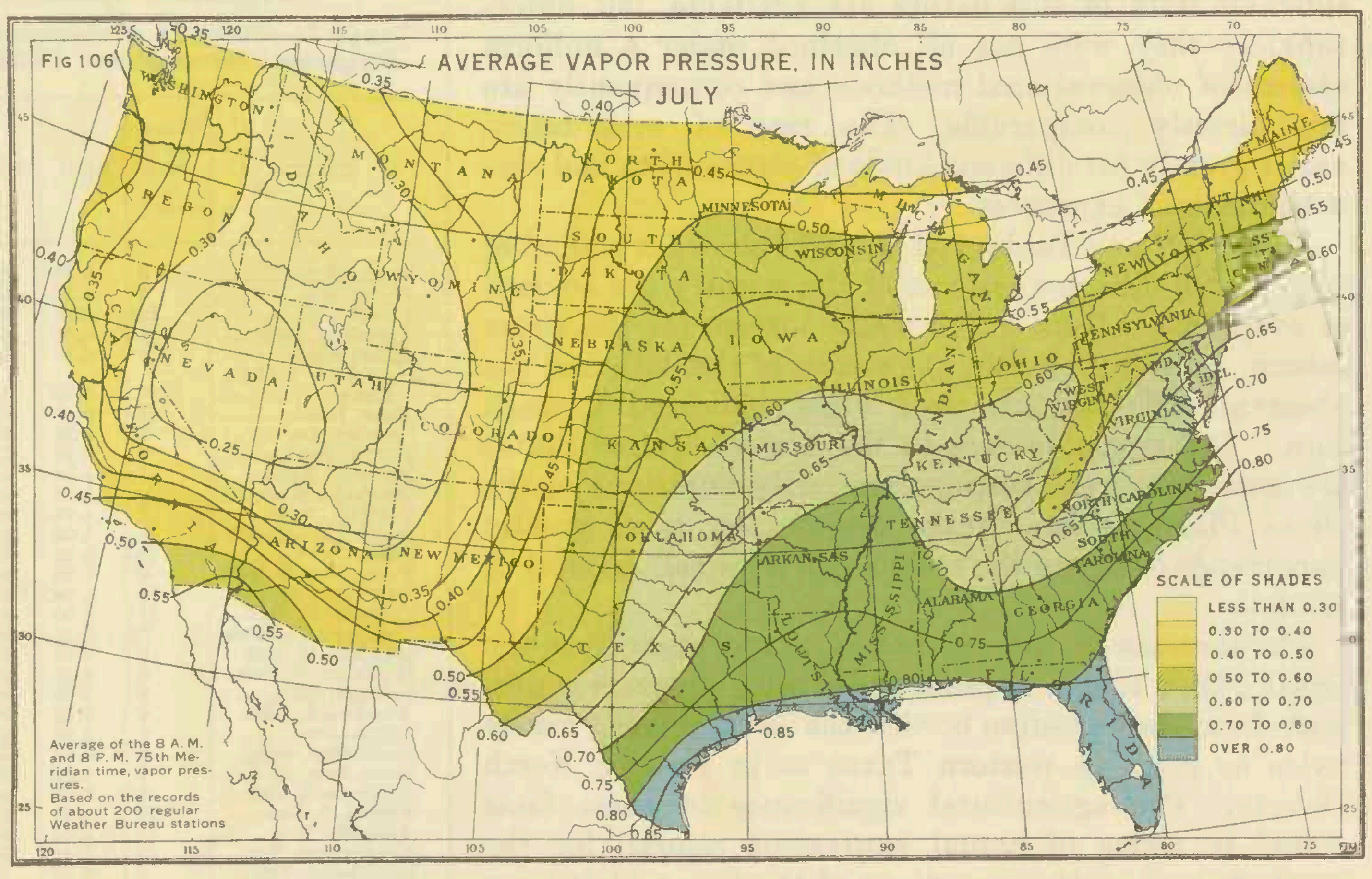


Figures 99, 100, and 101 show for the months of April, July, and October, the average daily minimum relative humidity computed from the average 8 p. m., 75th meridian time, vapor pressure, and the saturation pressure corresponding to the average daily maximum temperature. This is made possible by the fact that diurnal variations in vapor pressure are small and the 8 p. m. values do not differ much from the averages at the time of maximum temperature. No effort was made to compute these values for January because the large fluctuations in temperature from day to day in winter and the frequency of temperatures below the freezing point, render computations of this character of doubtful accuracy. Except at a few stations where hygrograph records have been made in recent years, no direct observations of the daily minimum relative humidity have been made by the Weather Bureau, hence the approximate values shown on these charts have been computed by the method indicated. The lowest relative humidity of the day occurs, as a rule, at about the time of maximum temperature, and the maximum relative humidity at about the time of minimum temperature. Figure 102 shows for the month of January the average absolute humidity as measured by the mean of the vapor pressure at 8 a. m. and 8 p. m., 75th meridian time. This mean does not differ much from the 24-hour average. In January the absolute humidity throughout the United States, except in Florida and along the Gulf Coast, is low, owing principally to the low temperature, being no greater than that in the Arid Interior Plateau in July (see fig. 106). The minimum in January, 0.05 inch, is in North Dakota, and the maximum, 0.55 inch, is in southern Florida.









Figures 103, 104, and 105 show for the months of April, July, and October the average depression of the wet-bulb temperature at the time of daily minimum relative humidity, which time corresponds closely to that of the maximum temperature. The values were computed from the average vapor pressure at 8 p. m., 75th meridian time, and the average daily maximum temperature. The high summer temperatures in arid and semi-arid climates are not so oppressive as indicated by the temperature records alone, since the dryness of the atmosphere affords increased opportunity for evaporation. In the far Southwest the wet-bulb temperature during the hottest part of the day in summer is often more than 30 degrees lower than the dry-bulb temperature; while at localities in the Great Lakes region it is less than 6 degrees. Figure 106 shows for the month of July the average absolute humidity as measured by the mean of the vapor pressure at 8 a. m. and 8 p. m., 75th meridian time. This mean does not differ much from the 24-hour average. In most of the United States, especially east of the Rocky Mountains, the geographic variations in the actual amount of moisture in the atmosphere, as shown by the vapor pressure, conform closely to those of temperature, decreasing from south to north and from summer to winter (see fig. 102). The minimum in July, 0.25 inch, is found in the Interior Plateau region, and the maximum, about 0.85 inch, occurs along the western Gulf Coast.

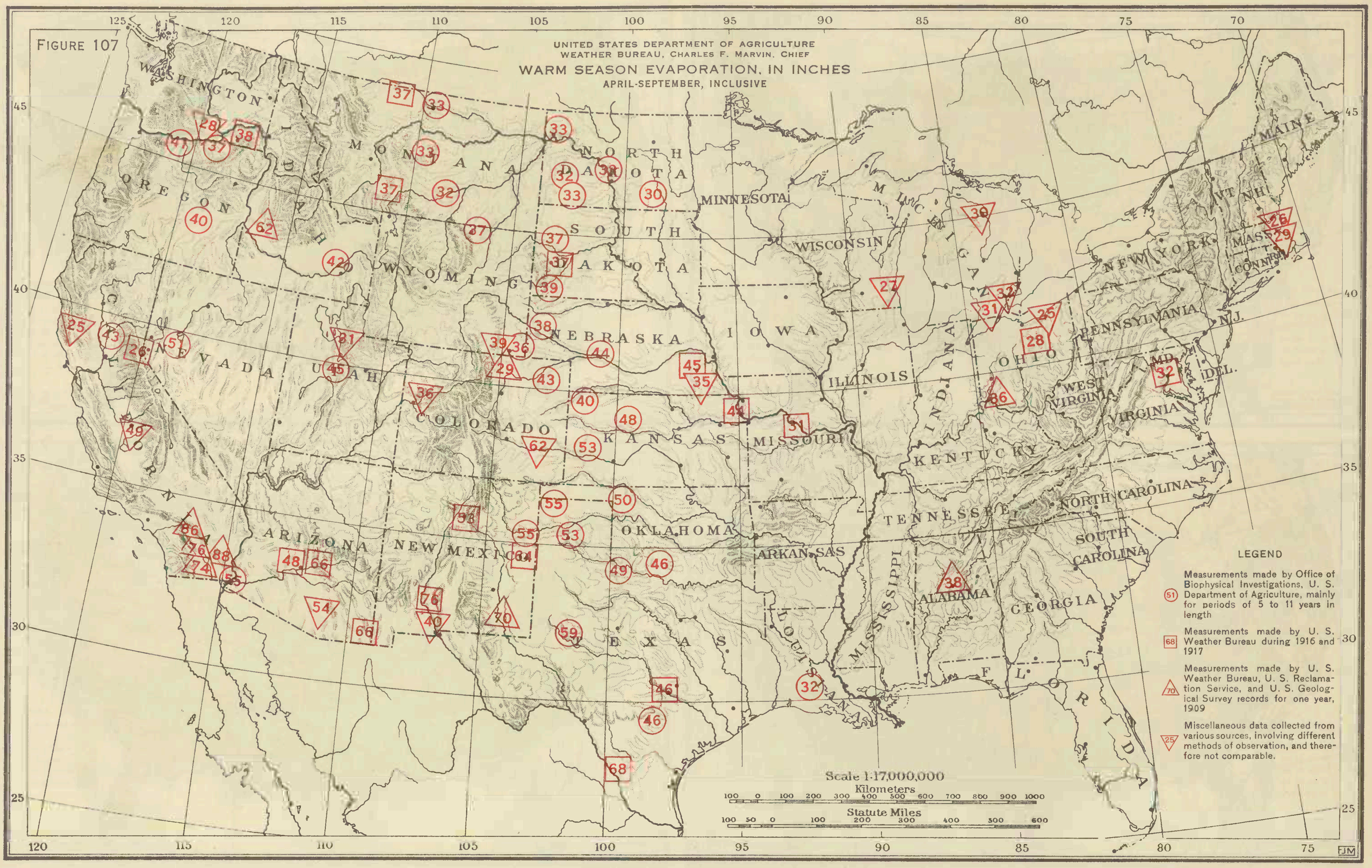


Figure 107 shows for a number of points in the United States the total evaporation, in inches, during the warm season, April to September, inclusive. The most extensive series of such observations are those made by the Office of Biophysical Investigations, Bureau of Plant Industry, in connection with their experimental work in the dry-farming regions of the West, and by the Weather Bureau. The observations by the Office of Biophysical Investigations were made from cylindrical pans 6 feet in diameter and 2 feet deep, sunk into the ground 20 inches, with the water level maintained at the height of the surface of the ground. Those made by the Weather Bureau were from cylindrical pans 4 feet in diameter and 20 inches deep, resting on a support, with the bottom of the pan about 6 inches above the surface of the ground. Evaporation from the Weather Bureau pans is somewhat greater than from those of the Bureau of Plant Industry, other things being equal, but data for each series are directly comparable among themselves. Of the two methods of exposure, that of the Bureau of Plant Industry probably more nearly represents actual evaporation from the soil, while the Weather Bureau method gives results typical of the meteorological conditions existing near the earth's surface. Records marked ○ are the average of observations, mostly 5 to 11 years in duration, made by the Office of Biophysical Investigations; those marked ▭ were made by the Weather Bureau during 1916 and 1917; those marked △ were collected by the Weather Bureau, U. S. Reclamation Service, and U. S. Geological Survey, and include only one year, 1909–10; while records marked ▽ were collected from various sources. Since different methods of observations were employed in securing the data on the map and in some cases different years are represented, the records are not directly comparable among themselves.

EVAPORATION.

In a study of the amount of rainfall usually received in a locality and its relation to agriculture, the question of loss of soil moisture by evaporation becomes of much importance, especially in regions where the available moisture supply borders on the minimum limit for the successful production of crops by ordinary methods of farming. The rate of evaporation of moisture from the soil depends principally upon the amount of moisture present, the soil texture, and the temperature, wind movement, and relative humidity of the atmosphere. Owing to the large variations in these several factors which control evaporation, and also to the varying rate of soil moisture loss by transpiration of plants and otherwise, a determination by direct observation of soil moisture loss by evaporation becomes of difficult accomplishment, and no extensive data showing this loss directly are available. Evaporation from a free water surface, however, gives some indication of the relative loss from the soil for different localities and considerable data of this nature are available, but unfortunately they were not all obtained under a uniform system of observational methods and consequently are not directly comparable. The rate of evaporation varies greatly for different kinds of atmometers and also with different exposures.

Figure 107 and Tables 1, 2, 3, and 4 show for a number of points in different sections of the country the amount of evaporation from a free water surface for the warm season, April–September, the source of the data and the observational methods used being indicated in each case. The available data in the eastern United States are scanty, but the stations are fairly numerous in the Great Plains region, where evaporation is of greater importance owing to the comparatively small amount of rainfall.

The increase in the amount of evaporation over the Great Plains region is pronounced with progress southward from the Canadian border, the amount being nearly twice as great in western Texas as in western North Dakota. The agricultural significance of these facts stated in terms of actual equivalent rainfall for the northern and southern portions of the Great Plains can only be approximately determined, since the influence of other factors, such as seasonal distribution of the rainfall in the southern portion and the more frequent torrential character of the precipitation, as compared with the northern portion, can not be separated from the effects of increased evaporation, but from some investigations that have been made it is concluded that from an agricultural standpoint 20 inches of annual rainfall in eastern North Dakota is equivalent to about 30 inches in southern Texas. It is interesting to observe the agricultural operations along a given isohyet. The 20-inch line of average annual precipitation extends in a north to south direction through the Great Plains region, conforming roughly to the 100th meridian of west longitude. This line in North Dakota passes through a region where the amount of moisture is usually ample for the successful production of wheat, oats, timothy hay, and other crops characteristic of a humid type of agriculture, but in Texas it passes through a country devoted largely to grazing and the growing of crops recognized as drought resistant, such as Kafir and milo.

JOSEPH BURTON KINCER.

AVERAGE WARM-SEASON EVAPORATION.

TABLE 1.—*Summary of measurements, in inches, made by the Office of Biophysical Investigations, United States Department of Agriculture.*

Station.	Number of years in record.	April.	May.	June.	July.	August.	September.	Average total, Apr.-Sept.
Yuma, Ariz.	9	7.76	9.54	10.58	10.21	9.61	7.43	55.13
Biggs, Calif.	4	4.47	6.25	8.64	9.60	8.15	6.38	43.49
Akron, Colo.	10	4.96	6.40	7.88	9.09	7.87	6.48	42.68
Aberdeen, Idaho	6	4.61	6.07	8.46	9.65	7.70	5.58	42.07
Colby, Kans.	4	4.35	5.90	7.48	8.69	7.47	6.02	39.91
Garden City, Kans	10	6.50	8.58	9.89	10.91	9.51	7.46	52.85
Hays, Kans.	11	6.16	7.04	8.42	9.97	9.29	7.02	47.90
Crowley, La.	7	4.85	5.69	6.18	5.72	5.36	4.54	32.34
Havre, Mont.	2	3.28	5.51	5.55	7.98	6.40	3.88	32.60
Huntley, Mont.	7	3.24	4.56	5.89	7.55	6.67	4.32	32.23
Moccasin, Mont.	9	3.83	4.93	5.56	6.78	7.06	4.62	32.78
Mitchell, Nebr.	7	4.83	6.16	7.43	7.97	6.80	5.26	38.45
North Platte, Nebr.	11	5.68	6.55	8.14	9.11	8.06	6.11	43.65
Fallon, Nev.	10	6.21	8.09	9.92	10.78	9.74	6.58	51.32
Tucumcari, N. Mex.	6	7.23	9.72	10.89	10.84	9.26	7.44	55.38
Dickinson, N. Dak.	10	4.04	4.64	6.25	6.80	5.98	4.08	31.79
Edgeley, N. Dak.	11	3.60	4.71	5.30	6.40	5.53	4.02	29.56
Hettinger, N. Dak.	7	4.16	4.93	6.40	7.45	5.91	3.92	32.77
Mandan, N. Dak.	5	3.78	5.15	6.06	7.37	6.45	4.49	33.30
Williston, N. Dak.	8	4.31	5.52	6.39	7.08	6.05	3.76	33.11
Lawton, Okla.	3	6.60	6.65	8.48	8.97	8.20	6.66	45.56
Woodward, Okla.	4	6.38	7.51	9.43	10.84	8.54	6.82	49.52
Burns, Oreg.	4	3.84	5.76	7.29	9.27	8.49	5.68	40.33
Hermiston, Oreg.	6	4.03	5.48	7.47	8.47	6.82	4.38	36.65
Moro, Oreg.	7	4.54	6.27	8.01	9.35	8.54	4.28	40.99
Ardmore, S. Dak.	5	3.81	5.24	7.21	8.71	7.56	6.06	38.59
Newell, S. Dak.	10	4.23	5.57	6.99	8.43	6.93	4.85	37.00
Amarillo, Tex.	11	7.03	8.79	10.17	10.38	9.11	7.23	52.71
Big Springs, Tex.	3	7.40	10.03	12.72	11.65	9.88	7.32	59.00
Chillicothe, Tex.	5	6.48	7.90	8.98	10.14	9.11	6.30	48.91
Dalhart, Tex.	10	7.49	9.52	10.56	10.61	9.63	7.58	55.39
San Antonio, Tex.	11	5.70	6.69	8.69	9.61	9.01	6.35	46.05
Nephi, Utah	10	4.56	6.16	8.78	9.52	9.23	6.36	44.61
Archer, Wyo.	5	3.65	5.06	7.17	7.95	6.88	5.63	36.34
Sheridan, Wyo.	1	3.14	4.91	5.82	9.81	7.85	5.14	36.67

TABLE 2.—*Summary of evaporation measurements, in inches, made by the Weather Bureau, United States Department of Agriculture.*

Station.	Year.	April.	May.	June.	July.	August.	September.	Total, April-September.
Mesa, Ariz.	1917	6.52	7.48	8.48	9.57	9.13	6.92	48.10
Roosevelt Reservoir, Ariz.	1916	8.56	12.38	14.77	13.38	11.55	9.63	70.27
	1917	7.74	10.12	13.23	13.48	12.09	9.57	66.23
Wilcox, Ariz.	1917	10.55	11.58	13.94	11.68	10.01	8.64	66.40
Yuma, Ariz.	1917	6.80	8.48	5.77	9.32	11.51	7.79	49.67
Tahoe, Calif.	1916	......	......	......	5.24	5.66	4.59	......
	1917	2.13	2.54	4.13	5.70	6.02	5.98	26.50
Washington, D. C. (American University).	1915	......	6.04	6.58	7.05	5.17	4.37	......
	1916	4.64	6.28	5.83	5.95	5.17	4.38	32.25
	1917	......	5.86	6.27	6.49	6.37	3.50	......
Arrowrock, Idaho	1916	......	......	......	8.86	8.53	6.14	......
	1917	......	4.42	7.52	10.17	......	5.53	......
Manhattan, Kans.	1917	5.68	5.70	8.66	11.06	7.01	5.44	43.55
Gardiner, Me.	1915	......	......	3.78	4.00	4.33	3.40	......
	1916	......	......	......	4.52	4.43	4.30	......
	1917	......	3.33	3.83	5.76	4.24	3.19	......
Columbia, Mo.	1916	3.45	4.99	5.16	7.52	6.54	3.84	31.50
	1917	3.58	4.45	6.26	7.28	5.49	3.81	30.87
Bozeman, Mont.	1917	1.92	5.90	7.07	9.49	8.07	4.84	37.29
Valier, Mont.	1917	2.76	5.40	6.99	10.84	8.06	3.28	37.33
Lincoln, Nebr.	1917	6.18	5.71	9.27	10.52	7.53	5.41	44.62
Elephant Butte Dam, N. Mex.	1916	......	15.47	16.87	11.83	9.55	9.11	......
	1917	12.92	13.50	15.29	13.25	11.81	9.00	75.77
Santa Fe, N. Mex.	1916	......	......	11.71	8.21	6.93	6.48	......
	1917	7.22	7.64	11.89	9.96	9.04	6.79	52.54
Tucumcari, N. Mex.	1917	9.34	9.40	13.44	13.76	10.46	7.20	63.60
Wooster, Ohio	1916	......	......	......	6.18	6.41	4.72	......
	1917	2.86	4.12	5.04	5.73	6.61	3.60	27.96
Rapid City, S. Dak.	1916	......	......	5.24	4.96	8.07	5.98	......
	1917	2.56	4.07	7.01	10.18	7.61	5.12	36.55
Austin, Tex.	1916	6.88	8.09	8.53	7.82	7.46	6.84	45.62
	1917	7.28	7.44	10.50	9.96	11.02	......	......
Laredo, Tex.	1917	10.91	10.18	11.72	13.67	13.15	8.76	68.39
Walla Walla, Wash.	1916	......	......	6.16	7.52	8.34	5.61	......
	1917	3.31	4.45	6.34	9.54	9.28	5.01	37.93

TABLE 3.—*Data collected by the U. S. Weather Bureau, U. S. Reclamation Service, and U. S. Geological Survey, comprising one year's record 1909–10. (See Abstract of Data No. 4, U. S. Weather Bureau.)*

Station.	Diameter of pan in feet.	Total, April-September.	Station.	Diameter of pan in feet.	Total, April-September.
Birmingham, Ala.	4	38.3	Mecca, Calif.	6	76.5
Brawley, Calif.	6	73.8	Deer Flat, Idaho	3	61.6
Indio, Calif.	6	86.5	Carlsbad, N. Mex.	4	69.7
Mammoth, Calif	6	88.2	California, Ohio	4	35.5

TABLE 4.—*Miscellaneous data (see Bul. 188 Bureau of Plant Industry).*

Station.	Period covered.	Total, April-September.	Station.	Period covered.	Total, April-September.
Tucson, Ariz.	1892–1894	54.2	Monroe, Mich.	1863–1867	30.9
Kingsburg Bridge, Calif.	1882–1885	49.2	Thunder Bay, Mich.	1862–1865	30.2
Lakeport, Calif.	1901–1902	25.3	Lincoln, Nebr.	1899–1909	34.8
Fort Collins, Colo.	1887–1902	29.3	Las Cruces, N. Mex.	1899–1901	40.1
Grand Valley, Colo.	1901	36.5	Cleveland, Ohio	1862–1867	24.6
Rocky Ford, Colo.	1901	61.6	Fort Douglas, Utah	1890–1892	30.7
Boston, Mass.: Beacon Hill	....	25.8	Prosser, Wash.	1900–1901	27.6
Chestnut Hill	....	28.6	Milwaukee, Wis.	1863–1867	26.9
Detroit, Mich.	1861–1864	32.1	Laramie, Wyo.	1893–1898	39.4

ADVANCE SHEETS, No. 8

ISSUED JULY 1935

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF CHEMISTRY AND SOILS
HENRY G. KNIGHT, Chief

ATLAS

OF

AMERICAN AGRICULTURE

PREPARED UNDER THE EDITORSHIP OF O. E. BAKER
SENIOR ECONOMIST, BUREAU OF AGRICULTURAL ECONOMICS

PART III

SOILS OF THE UNITED STATES

BY

C. F. MARBUT
PRINCIPAL SOIL SCIENTIST, IN CHARGE OF SOIL SURVEY
BUREAU OF CHEMISTRY AND SOILS

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1935

FOREWORD

The soil map in this publication, as well as the descriptions of soils in the accompanying text, are based almost exclusively on the accumulated results of the Soil Survey of the United States Department of Agriculture and on such general information regarding soil characteristics as has been obtained by traveling across the country in carrying on the work of the Soil Survey during the last 35 years. In the mountainous parts of the country, in the deserts of the Great Basin region, and in the western part of the Great Plains, large areas have not yet been mapped. These areas are shown uncolored on the small map, plate 5, section 9, showing the relative reliability of the data. In such areas the soil map is based on very general information.

In certain small areas, like parts of the lake region and smaller areas in nearly every State, the map is based on information obtained by many journeys across them, made by members of the Soil Survey staff, as well as from suggestions obtained from the soil maps of surrounding areas. The information regarding these small unsurveyed areas is much greater and more accurate than that in the unsurveyed parts of the mountains, deserts, and Great Plains of the West. In all cases the map has been constructed on the basis of soil information only, and not on inferences derived from a consideration of climate, vegetation, or other feature of the natural environment.

Soil surveying was begun in the United States in 1899. From the beginning, the work was done in great detail, the point of view being agricultural. At that time, soils were looked upon, in the United States, merely as geological formations utilized by nature for the growth of plants. Such chemical data regarding them as had accumulated up to that time, were interpreted entirely in terms of their significance as indicators of soil productivity. All other soil characteristics were considered as expressions of geological derivation or of agricultural significance. None of the data, which later demonstrated with convincing clearness the intimate connection of soil characteristics with the features of the climatic and vegetative environment of the locality in which they developed, had been accumulated, or if accumulated, their significance had not been discovered.

Surveys made during the first few years were of local significance. Each area covered was a unit in itself. The soil units defined were at first based largely on texture of the surface soil to the usual depth of plowing. Within a few years, however, the desirability of determining the relationships or kinships of the soils, isolated, defined, and mapped in all projects throughout the country, became apparent.

The successive steps in the evolution of the Soil Survey from this simple beginning to its present status as an institution concerned with all the characteristics of the soil, the processes of soil development, and the relationships of soil units throughout the United States, not only to themselves but to the several factors of the environment in which they were developed, have been very briefly outlined in the accompanying text.

The accumulated facts, on the basis of which the soil map has been constructed and the report prepared, excepting the chemical data presented, are derived from these sources, differing mainly in the degree of detail to which the field studies were carried out. These are: (a) detailed soil surveys, (b) reconnaissance soil surveys, and (c) general studies made by myself, the inspectors in the Soil Survey, and the field men of the Soil Survey. The latter studies have been made in areas for which the other kinds of data have not been accumulated.

The large amount of analytical data on the chemical and mechanical composition of soils published in this report was supplied to the Soil Survey by the Division of Soil Chemistry and Physics of the Bureau of Chemistry and Soils on samples collected by the Soil Survey staff.

The chemical methods used in making these analyses, from which these data are derived, are fully explained in a special section on page 97.

The accompanying report and soil map constitute the results of an interpretation and systematization of all these data. Because of the impossibility of including all the detailed data on one small map of the United States, this work has involved the selection of the most significant data for each region and elimination of the less significant. In order to do this, it has been necessary to familiarize myself with at least the general features of the soils of the whole country. This, in turn, has required a great amount of travel. Part of this travel was performed in the course of the routine inspection of Soil Survey work, but much additional travel was necessary to acquire knowledge for the purposes of this report alone. This made it necessary to travel, in some cases more than once, to parts of the country for which the presentation of a specific and convincing reason for the travel to one who did not have in mind all the details of the ultimate purpose involved, was somewhat difficult. Notwithstanding this, throughout a period of a quarter of a century, the administrative officers of the Bureau of Soils, later the Bureau of Chemistry and Soils, have never raised a serious question regarding any trip for which I requested authorization. During the period when practically all this travel was performed, Prof. Milton Whitney was chief of the Bureau of Soils. His administrative work did not allow him to become familiar with the purpose for the travel, but to his honor it may be said that his confidence in the men whom he had brought into his organization prompted him to support them consistently in employing time and expending money for work, the full significance of which was not perfectly evident at that time.

The material had been collected and the map and text were well along toward completion when the existing set-up of the Bureau of Chemistry and Soils, of which the Soil Survey is a part, was established. The new administrative officers have pushed forward, consistently and uninterruptedly, the publication of the results, a task not easily accomplished in the face of high cost and reduced appropriations.

The working out of the scheme of classification of soils, presented in this report and map, has required close familiarity with work of this kind throughout the world. This has been necessary in order to make the results capable of interpretation in the light of the broad principles of soil science now well worked out and made applicable to all parts of the world.

No two continents of the world are identical. Principles worked out on the basis of conditions in one continent cannot be applied without modification in any other. Although the report and map presented here have been constructed through an interpretation of American soil facts in terms of general principles of pedological science, adjustments have been made to fit special conditions. Any mistakes that have been made in such adjustments must be charged to the author alone and not to his many loyal associates to whom he is indebted for the faithful, patient collection of the factual data on which the whole work is based.

Although the actual data presented in this report are contained mainly in the reports and maps of the Soil Survey, the principles of pedology, according to which the material has been interpreted and arranged, are contained in pedological literature. Following is a list of highly important publications in which these principles are embodied.

Curtis F. Marbut.

PEDOLOGICAL LITERATURE

AARNIO, B.

(1) EXPERIMENTELLE UNTERSUCHUNGEN ZUR FRAGE DER AUSFÄLLUNG DES EISENS IN PODSOLBÖDEN. Internatl. Mitt. Bodenk. 3: 131–140. 1913.

——— (2) ÜBER DIE AUSFÄLLUNG DES EISENOXYDES UND DER TONERDE IN FINNLÄNDISCHEN SAND- UND GRUSBÖDEN. Finnland Geol. Komm. Geotek. Meddel 16, 76 pp., illus. 1915.

——— (3) ÜBER SALZBÖDEN (ALAUNBÖDEN) DES HUMIDEN KLIMAS IN FINNLAND. Compt. Rend. Conf. Agr. [Prague] 3: 186–192. 1924.

——— (4) CHEMICAL AND PHYSICAL PROPERTIES OF FINNISH SOILS. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 507–523, illus. 1928.

——— and STREMME, H.

(5) ZUR FRAGE DER BODENBILDUNG UND BODENKLASSIFIKATION. Geol. Landesanst. Finland Agrogeol. Mitt. 17, 48 pp., illus. 1924.

AKIMTZEV, V. V.

(6) HISTORICAL SOILS OF THE KAMENETZ-PODOLSK FORTRESS. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 132–140, illus. 1932.

——— (7) ON THE CHERNOZEMS OF WEST SIBERIA. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 201–208, illus. 1932.

ANDERSEN, J.

(8) CLASSIFICATION DU SOL DE DANEMARK. *In* Frosterus, B., Memoires sur la Nomenclature et la Classification des Sols. Internatl. Comn. Soil Sci. Geol. Survey Finland. 1924.

ANDERSON, M. S., and BYERS, H.

(9) CHARACTER OF THE COLLOIDAL MATERIALS IN THE PROFILES OF CERTAIN MAJOR SOIL GROUPS. U. S. Dept. Agr. Tech. Bull. 228, 24 pp. 1931. (See 1.)

——— and MATTSON, S.

(10) PROPERTIES OF THE COLLOIDAL SOIL MATERIAL. U. S. Dept. Agr. Bull. 1452, 47 pp., illus. 1926.

ATTERBERG, A.

(11) DIE PLASTIZITAT DER TONE. Internatl. Mitt. Bodenk. 1: 10–43, illus. 1911.

——— (12) DIE MECHANISCHE BODENANALYSE UND DIE KLASSIFIKATION DER MINERALBÖDEN SCHWEDENS. Internatl. Mitt. Bodenk. 2: [312]–342, illus. 1912. (See 2.)

——— (13) DIE PLASTIZITÄT UND BINDIGKEIT LIEFERNDEN BESTANDTEILE DER TONE. Internatl. Mitt. Bodenk. 3: 291–330, illus. 1913.

BAILEY, E. H.

(14) THE EFFECT OF AIR DRYING ON THE HYDROGEN-ION CONCENTRATION OF THE SOILS OF THE UNITED STATES AND CANADA. U. S. Dept. Agr. Tech. Bull. 291, 44 pp., illus. 1932.

BALDWIN, M.

(15) SOME CHARACTERISTIC SOIL PROFILES IN THE NORTH CENTRAL STATES. Amer. Soil Survey Assoc. Bull. 7: 122–132. 1926.

——— (16) THE GRAY-BROWN PODSOLIC SOILS OF THE EASTERN UNITED STATES. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 276–282. 1928.

BALLENEGER, R.

(17) SUR LA COMPOSITION CHIMIQUE DES SOLS DE LA HONGRIE. Actes 4 Conf. Internatl. Pedol. [Rome] 3: 419–433, illus. 1926.

BAVER, L. D., and SCARSETH, G. D.

(18) SUBTROPICAL WEATHERING IN ALABAMA AS EVIDENCED IN THE SUSQUEHANNA FINE SANDY LOAM PROFILE. Soil Research 2: 288–307, illus. 1931.

BENNETT, H. H., and ALLISON, R. V.

(19) THE SOILS OF CUBA. 410 pp., illus. Washington, D. C. 1928.

BJÖRLYKKE, K. O.

(20) SOIL TYPES AND SOIL PROFILES IN NORWAY. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 223–269, illus. 1928.

BLANCK, E.

(21) HANDBUCH DER BODENLEHRE. 10 v., illus. Berlin. 1929–32.

BRADFIELD, R.

(22) THE NATURE OF THE ACIDITY OF THE COLLOIDAL CLAY OF ACID SOILS. Jour. Amer. Chem. Soc. 45: 2669–2678. 1923.

——— (23) THE CHEMICAL NATURE OF COLLOIDAL CLAY. Jour. Amer. Soc. Agron. 17: 253–270, illus. 1925.

——— (24) VARIATIONS IN CHEMICAL AND MECHANICAL COMPOSITION IN SOME TYPICAL MISSOURI SOIL PROFILES. Amer. Soil Survey Assoc. Bull. 6: 127–145, illus. 1925.

BRAY, R. H., and DE TURK, E. E.

(25) CHEMICAL ASPECTS OF SOME ILLINOIS SOILS AS RELATED TO THEIR GENESIS AND MORPHOLOGY. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 118–131. 1932.

BRIGGS, L. J., and MCLANE, J. W.

(26) THE MOISTURE EQUIVALENTS OF SOILS. U. S. Dept. Agr., Bur. Soils Bull. 45, 23 pp., illus 1907.

——— and SHANTZ, H. L.

(27) THE WILTING COEFFICIENT FOR DIFFERENT PLANTS AND ITS INDIRECT DETERMINATION. U. S. Dept. Agr., Bur. Plant Indus. Bull. 230, 83 pp., illus. 1912.

BROWN, I. C.

(28) A STUDY OF CLAYPAN SOILS. U. S. Dept. Agr. Tech. Bull. 399, 43 pp. 1933.

——— and BYERS, H. G.

(29) THE FRACTIONATION, COMPOSITION, AND HYPOTHETICAL CONSTITUTION OF CERTAIN COLLOIDS DERIVED FROM THE GREAT SOIL GROUPS. U. S. Dept. Agr. Tech. Bull. 319, 44 pp. 1932.

BUSHNELL, T. M.

(30) A KEY TO SOIL PROFILES IN INDIANA. First Internatl. Cong. Soil Sci., Proc. and Misc. Papers 4: 909–914. 1928.

BYERS, H. G., and ANDERSON, M. S.

(31) THE COMPOSITION OF SOIL COLLOIDS IN RELATION TO SOIL CLASSIFICATION. Jour. Phys. Chem. 36: [348]–366. 1932.

CAMPBELL, J. M.

(32) LATERITE—ITS ORIGIN, STRUCTURE, AND MINERALS. Mining Mag. 17: 67–77, 120–128, 171–179, 220–229. 1917. (See 3.)

CARTER, W. T.

(33) THE SOILS OF TEXAS. Tex. Agr. Expt. Sta. Bull. 431, 192 pp., illus. 1931.

CLARKE, F. W.

(34) DATA OF GEOCHEMISTRY. U. S. Geol. Survey Bull. 330, 716 pp. 1908.

COBB, W. B.

(35) A COMPARISON OF THE DEVELOPMENT OF SOILS FROM ACIDIC AND BASIC ROCKS. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 456–465, illus. 1928.

COFFEY, G. N.

(36) THE DEVELOPMENT OF SOIL SURVEY WORK IN THE UNITED STATES WITH A BRIEF REFERENCE TO FOREIGN COUNTRIES. Amer. Soc. Agron. Proc. 3: 115–129. 1912.

COMBER, N. M.

(37) AN INTRODUCTION TO THE SCIENTIFIC STUDY OF THE SOIL. Ed. 2, 208 pp., illus. New York and London. 1932.

CONREY, G. W., and PASCHALL, A. H.

(38) A KEY TO THE SOILS OF OHIO. Ohio Agr. Expt. Sta. Spec. Circ. 44, 32 pp., illus. 1934.

CROWTHER, E. M.

(39) CLIMATE, CLAY COMPOSITION, AND SOIL TYPE. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 15–23, illus. 1932.

DAVIS, R. O. E., and BRYAN, H.

(40) THE ELECTRICAL BRIDGE FOR THE DETERMINATION OF SOLUBLE SALTS IN SOILS. U. S. Dept. Agr., Bur. Soils Bull. 61, 36 pp., illus. 1910.

DOKUCHAIEV, V. V.

(41) RUSSKII CHERNOSEM . . . [RUSSIAN CHERNOZEM.] 376 pp., illus. St. Petersburg. 1883.

DOSMANOVA, O. P.

(42) CONTRIBUTION TO THE STUDY OF THE GLEY FORMATION PROCESS. *In* To the Memory of K. K. Gedroiz, Dokuchaiev Soil Inst. Acad. Sci. U. S. S. R. Trans. 9: 161–188. 1934. [In Russian. English summary, pp. 187–188. Table of Contents in English.]

ELLIS, J. H.

(43) A FIELD CLASSIFICATION OF SOILS FOR USE IN THE SOIL SURVEY. Sci. Agr. 12: 338–345. 1932.

ENCULESCU, P.

(44) LES ZONES DE VEGETATION LIGNEUSE DE ROUMANIE EN RAPPORT AVEC LES CONDITIONS ORO-HYDROGRAPHIQUES, CLIMATERIQUES, DE SOL ET DE SOUS-SOL. 338 pp., illus. Bucuresti. 1924. (Rumania Institutul geologic. Memoriile, v. 1.)

FALCONER, J. G., and MATTSON, S.

(45) THE LAWS OF SOIL COLLOIDAL BEHAVIOR. XIII. OSMOTIC IMBIBITION. Soil Sci. 36: 317–327. 1933.

FLETCHER, C. C., and BRYAN, H.

(46) MODIFICATION OF THE METHOD OF MECHANICAL SOIL ANALYSIS. U. S. Dept. Agr., Bur. Soils Bull. 84, 16 pp., illus. 1912.

FLOROV, N.

(47) ÜBER DIE DEGRADIERUNG DES TSCHERNOSIOMS IN DEN WALDSTEPPEN. 144 pp., illus. Bukarest. 1926.

——— (48) EINIGES ÜBER DIE ORGANISATION DER UNTERSUCHUNG DER "BRAUNERDEN." Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 190–191. 1932.

FROSTERUS, B.

(49) ZUR FRAGE NACH DER EINTEILUNG DER BÖDEN IN NORDWEST-EUROPAS MORÄNGEBIET. III. UEBER DIE EINTEILUNG DER BODENABLAGERUNGEN IN MORÄNENGEBIETEN NACH DER KORNGRÖSSE UND PHYSIKALISCHEN EIGENSCHAFTEN. Finland Geol. Komm. Geotek. Meddel. 12, 25 pp., illus. 1913.

FROSTERUS, B.

(50) ZUR FRAGE NACH DER EINTEILUNG DER BÖDEN IN NORDWEST-EUROPAS MORÄNGEBIET. IV. BEITRAG ZUR KENNTNIS DER BODENBILDUNG IN TONEN DER HUMIDEN GEGENDEN. Finland Geol. Komm. Geotek. Meddel. 13, 31 pp., illus. 1914. (Also in Internatl. Mitt. Bodenk. 3.)

——— (51 DIE KLASSIFIKATION DER BODEN UND BODENARTEN FINNLANDS. Geol. Komm. Finland, Agrogeol. Meddel. no. 18, 39 pp., illus. Helsingfors, Finland. 1924. (See 6.)

——— and GLINKA, K. D.

(52) ZUR FRAGE NACH DER EINTEILUNG DER BÖDEN IN NORDWEST-EUROPAS MORÄNGEBIET I AND II. Finland Geol. Komm. Geotek. Meddel. 11, 16 pp. 1912.

GEDEVANISHVILI, D. P.

(53) GENESIS AND GEOGRAPHICAL DISTRIBUTION OF PODZOLISED RED SOILS IN WEST GEORGIA. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 241–246. 1932.

GERASIMOV, I. P., and IVANOVA, E. N.

(54) ON THE PROCESS OF CONTINENTAL SALT ACCUMULATION IN THE SOILS, ROCKS, UNDERGROUND WATERS AND LAKES OF THE KULUNDA STEPPE (WESTERN SIBERIA). *In* To the Memory of K. K. Gedroiz, Dokuchaiev Soil Inst. Acad. Sci. U. S. S. R. Trans. 9: 101–136, illus. 1934. [In Russian. English summary, pp. 133–135. Table of Contents in English.]

GEVELSON, T. A.

(55) ON THE QUESTION OF THE ROLE OF VEGETATION IN THE PROCESS OF CONTINENTAL SALT ACCUMULATION. *In* To the Memory of K. K. Gedroiz, Dokuchaiev Soil Inst. Acad. Sci. U. S. S. R. Trans. 9: 137–159. 1934. [In Russian. English summary, pp. 158–159. Table of Contents in English.]

GILE, P. L.

(56) THE EFFECT OF DIFFERENT COLLOIDAL SOIL MATERIALS ON THE EFFICIENCY OF SUPERPHOSPHATE. U. S. Dept. Agr. Tech. Bull. 371, 50 pp., illus. 1933.

——— MIDDLETON, H. E., ROBINSON, W. O., FRY, W. H., and ANDERSON, M. S.

(57) ESTIMATION OF COLLOIDAL MATERIAL IN SOILS BY ADSORPTION. U. S. Dept. Agr. Bull. 1193, 42 pp. 1924.

GLINKA, K. D.

(58) DIE TYPEN DER BODENBILDING, IHRE KLASSIFIKATION UND GEOGRAPHISCHE VERBREITUNG. 365 pp., illus. Berlin. 1914.

——— (59) DIE DEGRADATION UND DER PODSOLIGE PROZEZ. Internatl. Mitt. Bodenk. 14: 40–49. 1924.

——— (60) THE GREAT SOIL GROUPS OF THE WORLD AND THEIR DEVELOPMENT. Transl. by C. F. Marbut. 235 pp. Ann Arbor, Mich. 1927. (Mimeographed.)

——— (61) POCHVOVEDENIE (SOIL SCIENCE—A TEXTBOOK). Izd. 4, 312 pp., illus. Moscow and Leningrad. 1933.

GORSHENIN, K. P.

(62) SIBERIAN CHERNOZEMS. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 273–284. 1932.

HARRASSOWITZ, H. I.

(63) LATERIT, MATERIAL UND VERSUCH, ERDGESCHICHTLICHER AUSWERTUNG. Fortschr. Geol. u. Paläontol. Bd. 4, Heft. 14: 253–566. 1926. (See 8.)

HILGARD, E. W.

(64) SOILS; THEIR FORMATION, PROPERTIES, COMPOSITION, AND RELATIONS TO CLIMATE AND PLANT GROWTH IN THE HUMID AND ARID REGIONS. 593 pp., illus. New York and London. 1906.

——— (65) DIE BÖDEN ARIDER UND HUMIDER LÄNDER. Internatl. Mitt. Bodenk. 1: 415–429. 1912.

HISSINK, D. J.

(66) VERSUCH EINER NOMENKLATUR UND KLASSIFIKATION DER NIEDERLAENDISCHEN BOEDEN, NEBST BEMERKUNGEN DER METHODIK. Actes 4 Conf. Internatl. Pedol. [Rome] 3: 474–479. 1926.

ILYIN, R. S.

(67) ON THE ORIGIN OF LOESS. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 63–66, illus. 1932.

JENNY, H.

(68) SOIL INVESTIGATIONS IN THE SWISS ALPS. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 421–428. 1928.

——— (69) RELATION OF TEMPERATURE TO THE AMOUNT OF NITROGEN IN SOILS. Soil Sci. 27: 169–188, illus. 1929.

JOEL, A. H.

(70) PREDOMINANT SASKATCHEWAN SOIL PROFILES CORRELATED WITH SOIL DEVELOPMENT FACTORS IN NORTHERN LATITUDES. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 200–222, illus. 1928.

JOFFE, J. S.

(71) SOIL PROFILE STUDIES. I. SOIL AS AN INDEPENDENT BODY AND SOIL MORPHOLOGY. Soil Sci. 28: 39–54. 1929.

——— (72) SOIL PROFILE STUDIES. III. THE PROCESS OF PODZOLIZATION. Soil Sci. 32: 303–323, illus. 1931.

——— (73) SOIL PROFILE STUDIES. IV. MORPHOLOGICAL AND CHEMICAL EVIDENCE OF PODZOLIZATION. Soil Sci. 33: 217–237, illus. 1932.

——— and LEE, L. L.

(74) SOIL PROFILE STUDIES. II. METHODS USED IN THE PROFILE SURVEY OF NEW JERSEY SOILS. Soil Sci. 28: 469–479, illus. 1929.

——— and PUGH, A. J.

(75) SOIL PROFILE STUDIES. VI. DISTRIBUTION OF TITANIUM IN SOILS WITH SPECIAL REFERENCE TO PODZOLS. Soil Sci. 38: 245–257. 1934.

——— and WATSON, C. W.

(76) SOIL PROFILE STUDIES. V. MATURE PODZOLS. Soil Sci. 35: 313–329. 1933.

KELLEY, W. P.

(77) A GENERAL DISCUSSION OF THE CHEMICAL AND PHYSICAL PROPERTIES OF ALKALI SOILS. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 483–489. 1928.

——— (78) THE DETERMINATION OF THE BASE-EXCHANGE CAPACITY OF SOILS AND A BRIEF DISCUSSION OF THE UNDERLYING PRINCIPLES. Jour. Amer. Soc. Agron. 21: 1021–1029. 1929.

——— and BROWN, S. M.

(79) REPLACEABLE BASES IN SOILS. Calif. Agr. Expt. Sta. Tech. Paper 15, 39 pp. 1924.

——— and BROWN, S. M.

(80) BASE UNSATURATION IN SOILS. First Internatl. Cong. Soil Sci. Comn. 2, Proc. and Papers 2: 491–507. 1928.

——— and BROWN, S. M.

(81) PRINCIPLES GOVERNING THE RECLAMATION OF ALKALI SOILS. Hilgardia 8, no. 5, pp. 149–177, illus. 1934.

KELLOGG, C. E.

(82) PRELIMINARY STUDY OF THE PROFILES OF THE PRINCIPAL SOIL TYPES OF WISCONSIN. Wis. Geol. and Nat. Hist. Survey Bull. 77A, 112 pp., illus. 1930.

——— (83) MORPHOLOGY AND GENESIS OF THE SOLONETZ SOILS OF WESTERN NORTH DAKOTA. Soil Sci. 38: 483–501, illus. 1934.

KERR, H. W.

(84) THE NATURE OF BASE EXCHANGE AND SOIL ACIDITY. Jour. Amer. Soc. Agron. 20: 309–335, illus. 1928.

KOSSOWITSCH, P.

(85) DIE SCHWARZERDE. Internatl. Mitt. Bodenk. 1: 199–354, illus. 1912.

KOVDA, V. A.

(86) CONTRIBUTION TO THE QUESTION OF THE FORMATION IN SOILS OF SECONDARY CALCIUM CARBONATES. *In* To the Memory of K. K. Gedroiz, Dokuchaiev Soil Inst. Acad. Sci. U. S. S. R. Trans. 9: 247–253. 1934. (In Russian. Table of Contents in English.)

LANG, R.

(87) VERSUCH EINER EXAKTEN KLASSIFIKATION DER BÖDEN IN KLIMATISCHEN UND GEOLOGISCHEN HINSICHT. Internatl. Mitt. Bodenk. 5: 315–346. 1915.

LEBEDEFF, A. F.

(88) DIE BEWEGUNG DES WASSERS IM BODEN UND IM UNTERGRUND. Ztschr. Pflanzenernähr. u. Düngung. (A) 10: 1–36, illus. 1927.

——— (89) THE DESIRABILITY OF MAPPING SPECIFIC SOIL PROPERTIES. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 494–497. 1928.

LE CROIX, A.

(90) LES LATERITES DE LA GUINEE ET LES PRODUITS D'ALTERATION QUI LEUR SONT ASSOCIES. Nouvelle Arch. Mus. Hist. Nat. [Paris] (5) 5: 255–358. 1913.

LUNDBLAD, K.

(91) BIDRAG TILL KANNEDOMEN OM BRUNJORDSELLER MULLJORDSTYPEN EGENSKAPER OCH DEGENERATION I SODRA SVERIGE. Meddel. Statens Skogsförsöksanst. [Sweden] 21: 1–48. 1924.

——— (92) STUDIES ON PODZOLS AND BROWN FOREST SOILS I. Soil Sci. 37: 137–155, illus. 1934.

LUNT, H. A.

(93) PROFILE CHARACTERISTICS OF NEW ENGLAND FOREST SOILS. Conn. Agr. Expt. Sta. Bull. 342: [739]–836, illus. 1932.

MCCOOL, M. M., VEATCH, J. O., and SPURWAY, C. H.

(94) SOIL PROFILE STUDIES IN MICHIGAN. Soil Sci. 16: 95–106. 1923.

MARBUT, C. F.

(95) THE CONTRIBUTION OF SOIL SURVEYS TO SOIL SCIENCE. Proc. Soc. Prom. Agr. Sci. 41st Ann. Meeting, pp. 116–142. 1920.

——— (96) A SCHEME FOR SOIL CLASSIFICATION. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 1–31, illus. 1928.

Marbut, C. F. (97)
MORPHOLOGY OF LATERITES. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 72–80. 1932.

Matthei, A. (98)
UEBER DIE GENESIS DER BÖDEN VON CHILE. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 536–539, illus. 1928.

——— (99)
EINFLUSS VON OBERFLÄCHENGESTALTUNG, KLIMA UND VEGETATION AUF DIE VERBREITUNG DER BODENTYPEN IN CHILE. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 84–90, illus. 1932.

Mattson, S. (100)
ELECTRODIALYSIS OF THE COLLOIDAL SOIL MATERIAL AND THE EXCHANGEABLE BASES. Jour. Agr. Research 33: 553–567, illus. 1926.

——— (101)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR I. Soil Sci. 28: 179–220, illus. 1929.

——— (102)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. II. CATAPHORESIS, FLOCCULATION, AND DISPERSION. Soil Sci. 28: 373–409, illus. 1929.

——— (103)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. III. ISOELECTRIC PRECIPITATES. Soil Sci. 30: 459–495, illus. 1930.

——— (104)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. IV. ISOELECTRIC PRECIPITATES. Soil Sci. 31: 57–77, illus. 1931.

——— (105)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. V. ION ADSORPTION AND EXCHANGE. Soil Sci. 31: 311–331. 1931.

——— (106)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. VI. AMPHOTERIC BEHAVIOR. Soil Sci. 32: 343–365. 1931.

——— (107)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. VII. PROTEINS AND PROTEINATED COMPLEXES. Soil Sci. 33: 41–72, illus. 1932.

——— (108)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. VIII. FORMS AND FUNCTIONS OF WATER. Soil Sci. 33: 301–322, illus. 1932.

——— (109)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. IX. AMPHOTERIC REACTIONS AND ISOELECTRIC WEATHERING. Soil Sci. 34: 209–240, illus. 1932.

——— (110)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. XI. ELECTRODIALYSIS IN RELATION TO SOIL PROCESSES. Soil Sci. 37: 149–163. 1933.

——— and Hester, J. B. (111)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. X. EXCHANGE NEUTRALITY AND COMBINING CAPACITY. Soil Sci. 34: 459–483, illus. 1932.

——— and Hester, J. B. (112)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. XII. THE AMPHOTERIC NATURE OF SOILS IN RELATION TO ALUMINUM TOXICITY. Soil Sci. 36: 229–244. 1933.

——— and Pugh, A. J. (113)
THE LAWS OF SOIL COLLOIDAL BEHAVIOR. XIV. THE ELECTROKINETICS OF HYDROUS OXIDES AND THEIR IONIC EXCHANGE. Soil Sci. 38: 299–313, illus. 1934.

Middleton, H. E., Slater, C. S., and Byers, H. G. (114)
PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOILS FROM THE EROSION EXPERIMENT STATIONS. U. S. Dept. Agr. Tech. Bull. 316, 51 pp. 1932.

——— Slater, C. S., and Byers, H. G. (115)
THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE SOILS FROM THE EROSION EXPERIMENT STATIONS—SECOND REPORT. U. S. Dept. Agr. Tech. Bull. 430, 63 pp., illus. 1934.

Mitscherlich, E. A. (116)
BODENKUNDE FÜR LAND- UND FORSTWIRTE. Aufl. 2, 317 pp., illus. Berlin. 1913.

Mohr, E. C. J. (117)
TROPICAL SOIL FORMING PROCESSES AND THE DEVELOPMENT OF TROPICAL SOILS, WITH SPECIAL REFERENCE TO JAVA AND SUMATRA. Transl. by R. L. Pendleton. Univ. Philippines Expt. Sta. Contrib. 655, Ed. 2, 213 pp. 1930. [Mimeographed.]

Morgan, M. F. (118)
THE SOILS OF CONNECTICUT. Conn. Agr. Expt. Sta. Bull. 320: [825]–911, illus. 1930.

Müller, P. E. (119)
STUDIEN ÜBER DIE NATÜRLICHEN HUMUSFORMEN UND DEREN EINWIRKUNG AUF VEGETATION UND BÖDEN. 324 pp., illus. Berlin. 1887.

Murgoci, G., ed. (120)
ÉTAT DE L'ÉTUDE DE LA CARTOGRAPHIE DU SOL DANS DIVERS PAYS. Fifth Comn. Internatl. Pedol. Bucharest. 1924.

Neustruev, S. S. (121)
ESSAY ON THE CLASSIFICATION OF SOIL FORMATION PROCESSES AS CONNECTED WITH THE GENESIS OF SOILS. *In* Afanasiev, J. N., The Classification Problem in Russian Soil Science. Russian Pedol. Invest. 5, Acad. Sci., pp. 48–51. Leningrad. 1927.

Niklas, H. (122)
UNTERSUCHUNGEN ÜBER BLEICHSAND- UND ORTERDE-BILDUNGEN IN WALDBÖDEN. Internatl. Mitt. Bodenk. 14: 50–54. 1924.

Nikiforov, C. (123)
THE PERPETUALLY FROZEN SUBSOIL OF SIBERIA. Soil Sci. 26: 61–81, illus. 1928.

Norton, E. A. (124)
PROFILES OF SOILS IN SOUTHERN ILLINOIS. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 283–290, illus. 1928.

——— and Winters, E. (125)
PEDOLOGICAL ASPECTS OF THE GENESIS AND MORPHOLOGY OF ILLINOIS SOILS. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 91–96. 1932.

Ogg, W. G. (126)
SCOTTISH SOILS IN RELATION TO CLIMATE AND VEGETATION. First Internatl. Cong. Soil Sci. Proc. 1: 301–309. 1928.

Olmstead, L. B., Alexander, L. T., and Middleton, H. E. (127)
A PIPETTE METHOD OF MECHANICAL ANALYSIS OF SOILS BASED ON IMPROVED DISPERSION PROCEDURE. U. S. Dept. Agr. Tech. Bull. 170, 23 pp., illus. 1930.

Pankov, A. M. (128)
THE SOIL ABSORBING COMPLEX AND THE PHYSICAL PROPERTIES OF SOILS. *In* To the Memory of K. K. Gedroiz, Dokuchaiev Soil Inst. Acad. Sci. U. S. S. R. Trans. 9: 237–245. 1934. [In Russian. English summary, p. 244. Table of Contents in English.]

——— and Shavryguin, P. I. (129)
ON THE CHARACTERISTICS OF THE COMPOSITION OF THE SOIL ABSORBING COMPLEX IN THE MANYCH RIVER REGION. *In* To the Memory of K. K. Gedroiz, Dokuchaiev Soil Inst. Acad. Sci. U. S. S. R. Trans. 9: 205–235. 1934. [In Russian. English summary, pp. 231–233. Table of Contents in English.]

Polynov, B. (130)
DAS MUTTERGESTEIN ALS FAKTOR DER BODENBILDUNG UND ALS KRITERIUM FÜR DIE BODENKLASSIFIKATION. Soil Research 2: 165–180. 1930.

Prescott, J. A. (131)
THE SOILS OF AUSTRALIA IN RELATION TO VEGETATION AND CLIMATE. Aust. Council Sci. and Indus. Research Bull. 52, 82 pp., illus. 1931.

Ramann, E. (132)
DIE WALDSTREU UND IHRE BEDEUTUNG FÜR BÖDEN UND WALD. NACH DEM GEGENWÄRTIGEN STANDE DER WISSENSCHAFT UND EIGENEN UNTERSUCHUNGEN, DARGESTELLT. 105 pp. Berlin. 1890.

——— (133)
DIE WANDERUNGEN DER MINERALSTOFFE BEIM HERBSTLICHEN ABSTERBEN DER BLÄTTER. Landw. Vers. Sta. 76: 157–164. 1912.

——— (134)
BODENBILDUNG UND BODENEINTEILUNG (SYSTEM DER BÖDEN). 118 pp. Berlin. 1918.

——— (135)
THE EVOLUTION AND CLASSIFICATION OF SOILS. Transl. by C. L. Whittles. 128 pp. England. 1928.

Reifenberg, A. (136)
BODENBILDUNG IM ROTERDEGEBIET. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 81–83. 1932.

Rice, T. D. (137)
SHOULD THE VARIOUS CATEGORIES IN A SCHEME OF SOIL CLASSIFICATION BE BASED ON SOIL CHARACTERISTICS OR ON THE FORCES AND CONDITIONS WHICH HAVE PRODUCED THEM? First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 108–112. 1928.

Robinson, G. W. (138)
THE NATURE OF CLAY, AND ITS SIGNIFICANCE IN THE WEATHERING CYCLE. Nature [London] 121: 903–904. 1928.

——— (139)
THE DEVELOPMENT OF THE SOIL PROFILE IN NORTH WALES AS ILLUSTRATED BY THE CHARACTER OF THE CLAY FRACTION. Jour. Agr. Sci. [England] 20: 618–639. 1930.

——— (140)
SOILS, THEIR ORIGIN, CONSTITUTION, AND CLASSIFICATION; AN INTRODUCTION TO PEDOLOGY. 390 pp., illus. London and New York. 1932.

Robinson, W. O (141)
METHOD AND PROCEDURE OF SOIL ANALYSIS USED IN THE DIVISION OF SOIL CHEMISTRY AND PHYSICS. U. S. Dept. Agr. Circ. 139, 20 pp. 1930.

——— and Holmes, R. S. (142)
THE CHEMICAL COMPOSITION OF SOIL COLLOIDS. U. S. Dept. Agr. Bull. 1311, 42 pp. 1924. (See 15.)

Romell, L. G. (143)
MULL AND DUFF AS BIOTIC EQUILIBRIA. Soil Sci. 34: 161–188. 1932.

Russell, Sir E. J. (144)
SOIL CONDITIONS AND PLANT GROWTH. Ed. 6, 636 pp., illus. London and New York. 1932.

Saidel, T. (145)
DIE BODENKARTE VON RUMÄNIEN, 1:1.500.000. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 477–478. 1928.

Scarseth, G. D. (146)
MORPHOLOGICAL, GREENHOUSE, AND CHEMICAL STUDIES OF THE BLACK BELT SOILS OF ALABAMA. Ala. Agr. Expt. Sta. Bull. 237, 48 pp., illus. 1932.

Shantz, H. L., and Marbut, C. F. (147)
THE VEGETATION AND SOILS OF AFRICA. Amer. Geogr. Soc., Research Ser. 13, 263 pp., illus. 1923.

Shaw, C. F. (148)
THE BASIS OF CLASSIFICATION AND KEY TO THE SOILS OF CALIFORNIA. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 65–103. 1928.

Sigmond, A. A. J. de (149)
CONTRIBUTION TO THE THEORY OF THE ORIGIN OF ALKALI SOILS. Soil Sci. 21: 455–479, illus. 1926.

——— (150)
HUNGARIAN ALKALI SOILS AND METHODS OF THEIR RECLAMATION. Calif. Agr. Expt. Sta. Spec. Pub., 156 pp., illus. 1927.

——— (151)
GENERAL PRINCIPLES FOR SURVEYING THE SALTY AND ALKALI SOILS. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 479–482. 1928.

Slater, C. S., and Byers, H. G. (152)
BASE EXCHANGE AND RELATED PROPERTIES OF THE COLLOIDS OF SOILS FROM THE EROSION EXPERIMENT STATIONS. U. S. Dept. Agr. Tech. Bull. 461, 20 pp. 1934.

Smolik, L. F. (153)
PRINCIPAL SOIL PROFILES OF CZECHOSLOVAKIA. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 323–327. 1928.

Snyder, E. F. (154)
METHODS FOR DETERMINING THE HYDROGEN-ION CONCENTRATION OF SOILS. U. S. Dept. Agr. Circ. 56, rev., 48 pp., illus. 1934.

Stebut, A. (155)
DIE BRAUNERDE (EIN BEITRAG ZUR THEORIE DER BRAUNERDEBILDUNG). Ztschr. Pflanzenernähr. u. Düngung (A) 15: 134–167. 1930.

——— (156)
LEHRBUCH DER ALLGEMEINEN BODENKUNDE. 518 pp., illus. Berlin. 1930.

Stepanov, N. N. (157)
DIE ZERSETZUNG DES LAUBABFALLS DER BÄUME UND STRÄUCHER. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 300–305, illus. 1932.

Stremme, H. G. (158)
GRUNDZÜGE DER PRAKTISCHEN BODENKUNDE. 332 pp., illus. Berlin. 1926.

——— (159)
GENERAL SOIL MAP OF EUROPE. First Internatl. Cong. Soil Sci. Comn. 4. 1927.

——— (160)
DIE BÖDEN DEUTSCHLAND. *In* Blanck's Handbuch der Bodenlehre v. 5, pp. 271–429. 1930.

——— (161)
VORLAGE DER NEUEN BODENKARTE EUROPAS. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5, 383–389. 1932.

Sumgin, M. (162)
CONDITIONS OF SOIL FORMATION IN THE REGION OF EVER-FROZEN. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 34–46, illus. 1932.

Tamm, O. (163)
OM SKOGSJORDSANALYSER. Meddel. Statens Skogsförsöksanst. [Sweden] 13–14: 235–260. 1917.

——— (164)
MARKSTUDIER I DET NORDSVENSKA BARRSKOGS-OMRÅDET. Meddel. Statens Skogsförsöksanst. [Sweden] 17: 49–300. 1920.

——— (165)
EINE METHODE ZUR BESTIMMUNG DER ANORGANISCHEN KOMPONETE DES GELKOMPLEXES IM BÖDEN. Meddel. Statens Skogförsöksanst. [Sweden] 19: 385–404. 1922.

——— (166)
DIE KLIMATISCHEN BODENREGIONEN IN SCHWEDEN. First Internatl. Cong. Soil Sci. Proc. 1: 269–285, illus. 1928.

——— (167)
DER BRAUNE WALDBODEN IN SCHWEDEN. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5:178–189, illus. 1932.

——— (168)
ÜBER DIE OXALATMETHODE IN DEN CHEMISCHEN BODENANALYSE. Meddel. Statens Skogförsöksanst. [Sweden] 27:1–20. 1932.

Thorp, J. (169)
THE EFFECTS OF VEGETATION AND CLIMATE UPON SOIL PROFILES IN NORTHERN AND NORTHWESTERN WYOMING. Soil Sci. 32: 283–301, illus. 1931.

Tiurin, I. V. (170)
THE WORK OF K. K. GEDROIZ IN THE PROVINCE OF SOIL CHEMISTRY. *In* To the Memory of K. K. Gedroiz, Dokuchaiev Soil Inst. Acad. Sci. U. S. S. R. Trans. 9: 33–44. 1934. (In Russian. Table of Contents in English).

Treitz, P. (171)
DIE BODENREGIONEN IM GESCHICHTLICHEN UNGARN UND DIE STELLUNG DER HAUPTBODENTYPEN ZU DER ALLGEMEINEN BODENKLASSIFIKATION. Actes 4 Conf. Internatl. Pedol. [Rome] 3: 434–439, illus. 1926.

——— (172)
PRELIMINARY REPORT ON THE ALKALI LAND INVESTIGATIONS OF THE HUNGARIAN GREAT PLAIN FOR 1926. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 589–614, illus. 1928.

Truog, E., and Chucka, J. A. (173)
THE ORIGIN, NATURE, AND ISOLATION OF THE INORGANIC BASE EXCHANGE COMPOUND OF SOILS. Jour. Amer. Soc. Agron. 22: 553–557. 1930.

Tumin, G. M. (174)
CHERNOZEM SOILS OF THE EUROPEAN PART OF THE USSR. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 261–272, illus. 1932.

Vageler, P. (175)
GRUNDRISS DER TROPISCHEN UND SUBTROPISCHEN BODENKUNDE. 216 pp., illus. Berlin. 1930.

Vanderford, C. F. (176)
THE SOILS OF TENNESSEE. Tenn. Agr. Expt. Sta. Bull. 10: 31–139, illus. 1897.

Vater, H. (177)
DIE BESCHREIBUNG DES STANDORTES ALS GRUNDLAGE ZUR BEURTEILUNG SEINES EINFLUSSES AUF DEN PFLANZENWUCHS. Internatl. Mitt. Bodenk. 6: 159–178, 209–229, 293–317. 1916.

Veatch, J. O. (178)
PROFILES OF SOILS IN THE GREAT LAKES REGION OF THE UNITED STATES. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 350–357, illus. 1928.

——— (179)
THE CLASSIFICATION OF ORGANIC SOILS. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 123–126. 1928.

Vilensky, D. G. (180)
THE CLASSIFICATION OF SOILS ON THE BASIS OF ANALOGOUS SERIES IN SOIL FORMATION. First Internatl. Soc. Soil Sci. Proc. 1: 1036–1053, illus. 1925.

——— (181)
ALKALI SOILS OF UKRAINA. *In* Contributions to the Study of the Soils of Ukraina no. 6, pp. 107–128, illus. Kharkov. 1927.

——— (182)
PRINCIPAL FEATURES OF DISTRIBUTION OF SOILS AND VEGETATION IN THE UNITED STATES. Soil Research 1: 108–137, illus. 1928.

——— (183)
BRIEF HISTORY AND PRINCIPAL SUMMARY OF INVESTIGATIONS OF SALINE AND ALKALI SOILS IN THE USSR. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 309–326, illus. 1932.

——— (184)
CONTRIBUTION TO THE QUESTION ON ESTABLISHING SYSTEMS OF THE TAXONOMIC UNITS OF THE SOIL COVER. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 175–177. 1932.

Villar, E. H. del (185)
LES SOILS MEDITÉRRANÉENS ÉTUDES EN ESPAGNE. First Internatl. Soc. Soil Sci. Proc. 5: 192–197. 1930.

Waksman, S. A. (186)
ON THE ORIGIN AND NATURE OF THE SOIL ORGANIC MATTER OR SOIL "HUMUS": V. THE ROLE OF MICROORGANISMS IN THE FORMATION OF "HUMUS" IN THE SOIL. Soil Sci. 22: 421–436. 1926.

Wheeting, L. C. (187)
SOME PHYSICAL AND CHEMICAL PROPERTIES OF SEVERAL SOIL PROFILES Mich. Agr. Expt. Sta. Tech. Bull. 62, 31 pp., illus. 1924.

Whitney, M. (188)
THE FUTURE OF THE SOIL SURVEY IN OUR NATIONAL AGRICULTURAL POLICY. Amer. Soil Survey Assoc. Bull. 5, pp. 1–3. 1924.

Whitson, A. R. (189)
SOILS OF WISCONSIN. Wis. Geol. and Nat. Hist. Survey Bull. 68, 270 pp., illus. 1927.

Wiegner, G. (190)
BÖDEN UND BODENBILDUNG IN KOLLOIDCHEMISCHER BETRACHTUNG. 98 pp., illus. Dresden and Leipzig. 1918.

Wolff, W. (191)
ÜBER DIE EINWIRKUNG DER GEOLOGISCHEN FORMATIONEN AUF DIE BODENBILDUNG IN NORDDEUTSCHLAND. Second Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 5: 53–62. 1932.

Wyatt, F. A., and Newton, J. D. (192)
ALBERTA SOIL PROFILES. First Internatl. Cong. Soil Sci. Comn. 5, Proc. and Papers 4: 358–366, illus. 1928.

Zakharov, S. A. (193)
THE PRINCIPAL SOIL TYPES OF THE CAUCASUS AND THEIR DISTRIBUTION. (Abstract) First Internatl. Cong. Soil Sci. Comn. Proc. 5, pp. 44–47. 1927.

——— (194)
THE STUDY OF THE MORPHOLOGY OF THE SOILS IN RUSSIA. (Abstract) First Internatl. Cong. Soil Sci. Comn. Proc. 5, pp. 38–40. 1927.

LIST OF DETAILED PROJECTS COVERED BY THE SOIL SURVEY

ALABAMA

(County Projects)

1908 Autauga.
1909 Baldwin.
1914 Barbour.
1908 Bibb.
1905 Blount.
1913 Bullock.
1907 Butler.
1908 Calhoun.
1909 Chambers.
1924 Cherokee.
1911 Chilton.
1921 Choctaw.
1912 Clarke.
1915 Clay.
1913 Cleburne.
1909 Coffee.
1933 Colbert.*
1912 Conecuh.
1929 Coosa.
1912 Covington.
1921 Crenshaw.
1908 Cullman.
1910 Dale.
1932 Dallas.*
1911 Elmore.
1913 Escambia.
1908 Etowah.
1917 Fayette.
1927 Franklin.
1920 Geneva.
1923 Greene.
1909 Hale.
1908 Henry.
1920 Houston.
1911 Jackson.
1908 Jefferson.
1908 Lamar.
1931 Lauderdale.*
1914 Lawrence.
1906 Lee.
1914 Limestone.
1916 Lowndes.
1904 Macon.
1911 Madison.
1920 Marengo.
1907 Marion.
1911 Marshall.
1930 Mobile.*
1916 Monroe.
1926 Montgomery.
1918 Morgan.
1930 Perry.*
1916 Pickens.
1910 Pike.
1911 Randolph.
1913 Russell.
1917 St. Clair.
1917 Shelby.
1904 Sumter.
1907 Talladega.
1909 Tallapoosa.
1911 Tuscaloosa.
1915 Walker.
1915 Washington.
1932 Wilcox.*
1932 Winston.*

ARIZONA

(Area Projects)

1921 Benson Area (part of Cochise County).
1927 Buckeye-Beardsley Area (part of Maricopa County).
1928 Gila Bend Area (part of Maricopa County).
1917 Middle Gila Valley Area (parts of Maricopa and Pinal Counties).
1930 Nogales Area (part of Santa Cruz County).
1928 Paradise-Verde Area (part of Maricopa County).
1926 Salt River Valley Area (part of Maricopa County).
1921 San Simon Area (part of Cochise County).
1931 Tucson Area (part of Pima County).*
1933 Upper Gila Valley Area (part of Graham County).*
1921 Winslow Area (parts of Coconino and Navajo Counties).
1929 Yuma-Wellton Area (part of Yuma County).

ARKANSAS

(County and Area Projects)

1913 Ashley.
1925 Bradley.
1914 Columbia.
1907 Conway.
1916 Craighead.
1917 Drew.
1917 Faulkner.
1906 Fayetteville Area (parts of Benton and Washington Counties).
1916 Hempstead.
1917 Howard.
1915 Jefferson.
1921 Lonoke.
1903 Miller.
1914 Mississippi.
1925 Nevada.
1920 Perry.
1913 Pope.
1906 Prairie.
1922 Pulaski.
1902 Stuttgart Area (part of Arkansas County).
1915 Yell.

CALIFORNIA

(Area Projects)

1931 Alturas Area (parts of Modoc and Lassen Counties).*
1916 Anaheim Area (parts of Orange and Los Angeles Counties).
1924 Auburn Area (parts of Nevada and Placer Counties).
1904 Bakersfield Area (part of Kern County).
1933 Barstow Area (part of San Bernardino County).*
1920 Big Valley Area (parts of Lassen and Modoc Counties).
1924 Bishop Area (parts of Inyo and Mono Counties).
1920 Brawley Area (part of Imperial County).
1907 Butte Valley Area (part of Siskiyou County).
1929 Capistrano Area (parts of San Diego and Orange Counties).
1925 Chico Area (part of Butte County).
1927 Clear Lake Area (part of Lake County).
1923 Coachella Valley Area (part of Riverside County).
1907 Colusa Area (parts of Glenn, Colusa, and Tehama Counties).
1933 Concord Area (part of Contra Costa County).
1931 Dixon Area (parts of Solano and Yolo Counties).*
1930 El Cajon Area (part of San Diego County).
1918 El Centro Area (part of Imperial County).
1921 Eureka Area (part of Humboldt County).
1912 Fresno Area (part of Fresno County).
1923 Gilroy Area (part of Santa Clara County).
1918 Grass Valley Area (part of Nevada County).
1901 Hanford Area (part of Kings County).
1915 Healdsburg Area (part of Sonoma County).
1923 Hollister Area (part of San Benito County).
1915 Honey Lake Area (part of Lassen County).
1924 King City Area (part of Monterey County).
1922 Lancaster Area (parts of Los Angeles and Kern Counties).
1910 Livermore Area (parts of Alameda and Contra Costa Counties).
1932 Lodi Area (part of San Joaquin County).*
1916 Los Angeles Area (part of Los Angeles County).
1910 Madera Area (part of Madera County).
1909 Marysville Area (parts of Sutter, Yuba, Colusa, and Sacramento Counties).
1914 Merced Area (part of Merced County).
1908 Modesto-Turlock Area (parts of Stanislaus, Merced, and San Joaquin Counties).
1933 Napa Area (part of Napa County).*
1929 Oceanside Area (part of San Diego County).
1926 Oroville Area (parts of Butte, Colusa, and Glenn Counties).
1908 Pajaro Valley Area (part of Santa Cruz County).
1922 Palo Verde Area (parts of Riverside and Imperial Counties).
1915 Pasadena Area (parts of Los Angeles and San Bernardino Counties).
1928 Paso Robles Area (part of San Luis Obispo County).
1927 Placerville Area (part of Eldorado County).
1908 Portersville Area (part of Tulare County).
1910 Red Bluff Area (part of Tehama County).
1907 Redding Area (part of Shasta County).
1915 Riverside Area (parts of San Bernardino and Riverside Counties).
1904 Sacramento Area (parts of Sacramento and Sutter Counties).

* Indicates areas surveyed, for which the report has not yet been published.

CALIFORNIA—Continued

1925 Salinas Area (part of Monterey County).
1915 San Fernando Valley Area (part of Los Angeles County).
1903 San Jose Area (parts of Santa Clara, San Mateo, and Alameda Counties).
1928 San Luis Obispo Area (part of San Luis Obispo County).
1916 Santa Maria Area (parts of San Luis Obispo and Santa Barbara Counties).
1927 Santa Ynez Area (part of Santa Barbara County).
1919 Shasta Valley Area (part of Siskiyou County).
1905 Stockton Area (part of San Joaquin County).
1930 Suisun Area (parts of Sacramento and Solano Counties).
1914 Ukiah Area (part of Mendocino County).
1917 Ventura Area (parts of Ventura and Los Angeles Counties).
1921 Victorville Area (part of San Bernardino County).
1918 Willits Area (part of Mendocino County).
1909 Woodland Area (parts of Yolo and Colusa Counties).
1908 Klamath Reclamation Project, Oregon (parts of Modoc and Siskiyou Counties).
1929 Yuma-Wellton Area, Arizona and California (part of Imperial County).

COLORADO

(Area Projects)

1926 Arkansas Valley Area (parts of Bent, Crowley, Fremont, Otero, Prowers, and Pueblo Counties).
1932 Brighton Area (parts of Adams, Boulder, and Jefferson Counties).*
1927 Fort Collins Area (parts of Larimer and Weld Counties).
1905 Grand Junction Area (part of Mesa County).
1929 Greeley Area (part of Weld County).
1930 Longmont Area (parts of Boulder and Weld Counties).*
1903 San Luis Valley Area (parts of Alamosa, Rio Grande, and Saguache Counties).
1910 Uncompahgre Valley Area (parts of Delta, Montrose, and Ouray Counties).

CONNECTICUT

(County and Area Projects)

1903 Connecticut Valley Area (parts of Hartford and Tolland Counties).
1912 New London.
1911 Windham.

DELAWARE

(County Projects)

1918 Kent.
1915 New Castle.
1920 Sussex.

FLORIDA

(County and Area Projects)

1913 Bradford.
1921 Duval.
1906 Escambia.
1918 Flagler.
1915 Fort Lauderdale Area (parts of Broward and Palm Beach Counties).
1915 Franklin.
1903 Gadsden.
1904 Gainesville Area (parts of Alachua, Levy, and Marion Counties).
1914 Hernando.
1916 Hillsborough.
1913 Indian River Area (parts of Broward, Indian River, Martin, Palm Beach, and St. Lucie Counties).
1907 Jefferson.
1923 Lake.
1905 Leon.
1909 Marianna Area (part of Jackson County).
1912 Ocala Area (parts of Citrus, Levy, Marion, and Sumter Counties).
1919 Orange.
1913 Pinellas.
1927 Polk.
1914 Putnam.
1917 St. Johns.

GEORGIA

(County and Area Projects)

1926 Bartow.
1912 Ben Hill.
1922 Bibb.
1916 Brooks.
1910 Bulloch.
1917 Burke.
1919 Butts and Henry.
1925 Calhoun.
1921 Carroll.
1911 Chatham.
1924 Chattahoochee.
1912 Chattooga.
1927 Clarke.
1914 Clay.
1901 Cobb.
1914 Colquitt.
1911 Columbia.
1928 Cook.
1919 Coweta and Fayette.
1916 Crisp.
1933 Decatur.*
1914 De Kalb.
1904 Dodge.
1923 Dooly.
1912 Dougherty.
1918 Early.
1928 Elbert.
1923 Fannin.
1917 Floyd.
1903 Fort Valley Area (parts of Peach, Houston, and Macon Counties).
1909 Franklin.
1911 Glynn.
1913 Gordon.
1908 Grady.
1919 Greene, Morgan, Oconee, and Putnam Counties.
1913 Habersham.
1909 Hancock.
1929 Hart.
1914 Jackson.
1916 Jasper.
1913 Jeff Davis.
1930 Jefferson.
1923 Jenkins.
1913 Jones.
1925 Lamar.
1915 Laurens.
1927 Lee.
1917 Lowndes.
1931 McDuffie.*
1929 McIntosh.
1918 Madison.
1916 Meriwether.
1913 Miller.
1920 Mitchell.
1920 Monroe.
1922 Muscogee.
1918 Pierce.
1909 Pike.
1914 Polk.
1918 Pulaski.
1926 Quitman.
1920 Rabun.
1924 Randolph.
1916 Richmond.
1920 Rockdale.
1920 Screven.
1905 Spaulding.
1913 Stewart.
1910 Sumter.
1913 Talbot.
1914 Tattnall.
1914 Terrell.
1908 Thomas.
1909 Tift.
1912 Troup.
1915 Turner.
1910 Walker.
1915 Washington.
1906 Waycross Area (part of Ware County).
1926 Wayne.
1915 Wilkes.
1929 Worth.

IDAHO

(County and Area Projects)

1926 Bear Lake Valley Area (part of Bear Lake County).
1930 Benewah.*
1903 Blackfoot Area (Bonneville, Bingham, and Jefferson Counties).
1901 Boise Area (parts of Ada and Canyon Counties).
1929 Gooding Area (parts of Elmore and Gooding Counties).
1927 Jerome Area (part of Jerome County).
1919 Kootenai.
1915 Latah.
1923 Minidoka Area (parts of Minidoka, Blaine, Cassia, Jerome, and Lincoln Counties).
1917 Nez Perce and Lewis.
1918 Portneuf Area (part of Bannock County).
1925 Soda Springs-Bancroft Area (parts of Bannock and Caribou Counties).
1921 Twin Falls Area (part of Twin Falls County).

ILLINOIS

(County and Area Projects)

1902 Clay.
1902 Clinton.
1903 Johnson.
1903 Knox.
1903 McLean.
1903 Sangamon.
1902 St. Clair.
1902 Tazewell.
1912 Will.
1903 Winnebago.
1904 O'Fallon Area, Missouri (parts of Calhoun and Jersey Counties).

INDIANA

(County and Area Projects)

1921 Adams.
1908 Allen.
1916 Benton.
1928 Blackford.
1912 Boone.
1904 Boonville Area (parts of Spencer and Warrick Counties).
1933 Cass.*
1922 Clay.
1914 Clinton.
1919 Decatur.
1913 Delaware.
1930 Dubois.*
1914 Elkhart.
1922 Gibson.
1915 Grant.
1906 Greene.
1912 Hamilton.
1925 Hancock.
1913 Hendricks.
1930 Jennings.*
1931 Knox.*
1922 Kosciusko.
1917 Lake.
1922 Lawrence.
1903 Madison.
1907 Marion.
1904 Marshall.
1927 Miami.
1922 Monroe.
1912 Montgomery.
1905 Newton.
1929 Ohio and Switzerland.*
1929 Pike.*
1916 Porter.
1902 Posey.
1925 Putnam.
1931 Randolph.*
1929 Rush.*
1904 Scott.
1915 Starke.
1933 Steuben.*
1905 Tippecanoe.
1912 Tipton.
1930 Vermillion.
1914 Warren.
1930 Washington.*
1925 Wayne.
1915 Wells.
1915 White.

IOWA

(County Projects)

1919 Adair.
1923 Appanoose.
1933 Audubon.*
1921 Benton.
1917 Black Hawk.
1920 Boone.
1913 Bremer.
1926 Buchanan.
1917 Buena Vista.
1928 Butler.
1930 Calhoun.
1926 Carroll.
1919 Cedar.
1903 Cerro Gordo.
1924 Cherokee.
1927 Chickasaw.
1923 Clarke.
1916 Clay.
1925 Clayton.
1915 Clinton.
1928 Crawford.
1920 Dallas.
1933 Davis.*
1922 Delaware.
1921 Des Moines.
1920 Dickinson.
1920 Dubuque.
1920 Emmet.
1919 Fayette.
1922 Floyd.
1932 Franklin.*
1924 Fremont.
1921 Greene.
1921 Grundy.
1929 Guthrie.
1917 Hamilton.
1930 Hancock.
1920 Hardin.
1923 Harrison.
1917 Henry.
1925 Howard.
1933 Ida.*
1921 Jasper.
1922 Jefferson.
1919 Johnson.
1924 Jones.
1925 Kossuth.
1914 Lee.
1917 Linn.
1918 Louisa.
1927 Lyon.
1918 Madison.
1919 Mahaska.
1932 Marion.*
1918 Marshall.
1920 Mills.
1916 Mitchell.
1931 Monroe.*
1917 Montgomery.
1914 Muscatine.
1921 O'Brien.
1921 Page.
1918 Palo Alto.
1923 Plymouth.
1928 Pocahontas.
1918 Polk.
1914 Pottawattamie.
1929 Poweshiek.
1916 Ringgold.
1928 Sac.
1915 Scott.
1915 Sioux.
1903 Story.
1904 Tama.
1927 Union.
1915 Van Buren.
1917 Wapello.
1925 Warren.
1930 Washington.
1918 Wayne.
1914 Webster.
1918 Winnebago.
1922 Winneshiek.
1920 Woodbury.
1922 Worth.
1919 Wright.

KANSAS

(County and Area Projects)

1904 Allen.
1931 Bourbon.*
1905 Brown.
1912 Cherokee.
1926 Clay.
1915 Cowley.
1928 Crawford.
1927 Doniphan.
1904 Garden City Area (parts of Finney and and Gray Counties).
1912 Greenwood.
1912 Jewell.
1928 Johnson.
1932 Kingman.*
1926 Labette.
1919 Leavenworth.
1930 Marion.*
1913 Montgomery.
1930 Neosho.*
1911 Reno.
1906 Riley.
1903 Russell Area (part of Russell County).
1911 Shawnee.
1902 Wichita Area (parts of Sedgwick and Butler Counties).
1927 Wilson.
1931 Woodson.*

* Indicates areas surveyed, for which the report has not yet been published.

KENTUCKY

(County Projects)

1912 Christian.
1931 Fayette.*
1921 Garrard.
1915 Jessamine.
1919 Logan.
1905 McCracken.
1905 Madison.
1903 Mason.
1930 Mercer.
1920 Muhlenberg.
1910 Rockcastle.
1903 Scott.
1916 Shelby.
1902 Union.
1904 Warren.

LOUISIANA

(Parish and Area Projects)

1903 Acadia.
1928 Beauregard.
1908 Bienville.
1906 Caddo.
1910 Concordia.
1904 De Soto.
1905 East Baton Rouge.
1908 East Carroll and West Carroll.
1912 East Feliciana.
1911 Iberia.
1915 Lafayette.
1901 Lake Charles Area (parts of Calcasieu and Jefferson Davis Parishes).
1918 La Salle.
1909 Lincoln.
1931 Livingston.*
1921 Natchitoches.
1903 New Orleans Area (parts of Jefferson, Orleans, Plaquemines, St. Charles, St. John the Baptist, and Lafourche Parishes).
1903 Ouachita.
1916 Rapides.
1919 Sabine.
1917 St. Martin.
1905 Tangipahoa.
1922 Washington.
1914 Webster.
1907 Winn.

MAINE

(County and Area Projects)

1917 Aroostook Area (part of Aroostook County).
1915 Cumberland.
1909 Orono Area (part of Penobscot County).

MARYLAND

(County Projects)

1921 Allegany.
1928 Anne Arundel.
1917 Baltimore.
1928 Calvert.
1929 Caroline.
1919 Carroll.
1927 Cecil.
1918 Charles.
1922 Dorchester.
1919 Frederick.
1922 Garrett.
1927 Harford.
1916 Howard.
1930 Kent.
1914 Montgomery.
1925 Prince Georges.
1931 Queen Annes.
1923 St. Marys.
1920 Somerset.
1929 Talbot.
1917 Washington.
1921 Wicomico.
1924 Worcester.

MASSACHUSETTS

(County Projects)

1920 Barnstable, Bristol, and Norfolk.
1923 Berkshire.
1925 Dukes and Nantucket
1925 Essex.
1929 Franklin.
1928 Hampden and Hampshire.
1924 Middlesex.
1911 Plymouth.
1922 Worcester.

MICHIGAN

(County and Area Projects)

1929 Alger.
1901 Allegan.
1904 Alma Area (northern part of Gratiot County).
1924 Alpena.
1923 Antrim.
1924 Barry.
1931 Bay.
1922 Berrien.
1928 Branch.
1916 Calhoun.
1906 Cass.
1927 Chippewa.
1927 Crawford.
1930 Eaton.
1912 Genesee.
1924 Hillsdale.
1933 Ingham.*
1930 Iron.*
1923 Isabella.
1926 Jackson.
1922 Kalamazoo.
1927 Kalkaska.
1926 Kent.
1923 Livingston.
1929 Luce.*
1923 Macomb.
1922 Manistee.
1927 Mecosta.
1925 Menominee.
1930 Montmorency.*
1924 Muskegon.
1933 Oceana.*
1923 Ogemaw.
1931 Oscoda.*
1922 Ottawa.
1904 Owosso Area (northern part of Shiawassee County).
1905 Oxford Area (northern part of Oakland County).
1903 Pontiac Area (southern part of Oakland County).
1924 Roscommon.
1933 Saginaw.*
1929 St. Clair.
1921 St. Joseph.
1932 Schoolcraft.*
1926 Tuscola.
1922 Van Buren.
1930 Washtenaw.
1908 Wexford.

MINNESOTA

(County and Area Projects)

1916 Anoka.
1906 Blue Earth.
1905 Carlton Area (parts of Carlton and St. Louis Counties).
1906 Crookston Area (part of Polk County).
1913 Goodhue.
1929 Hennepin.
1929 Houston.
1930 Hubbard.*
1923 Jackson.
1933 Kanabec.*
1924 Lac Qui Parle.
1903 Marshall Area (part of Lyon County).
1927 Mille Lacs.
1923 Olmsted.
1914 Pennington.
1914 Ramsey.
1909 Rice.
1919 Stevens.
1926 Wadena.
1904 Superior Area, Wisconsin (part of St. Louis County).

MISSISSIPPI
(County and Area Projects)

1910 Adams.
1921 Alcorn.
1917 Amite.
1915 Chickasaw.
1920 Choctaw.
1926 Claiborne.
1914 Clarke.
1909 Clay.
1915 Coahoma.
1917 Covington.
1911 Forrest.
1922 George.
1932 Greene.*
1915 Grenada.
1930 Hancock.
1924 Harrison.
1916 Hinds.
1908 Holmes.
1927 Jackson.
1907 Jasper.
1915 Jefferson Davis.
1913 Jones.
1912 Lafayette.
1919 Lamar.
1910 Lauderdale.
1916 Lee.
1912 Lincoln.
1911 Lowndes.
1917 Madison.
1908 Monroe.
1906 Montgomery.
1916 Newton.
1910 Noxubee.
1907 Oktibbeha.
1918 Pearl River.
1922 Perry.
1918 Pike.
1906 Pontotoc.
1907 Prentiss.
1926 Rankin.
1919 Simpson.
1902 Smedes Area (parts of Yazoo, Madison, Issaquena, and Sharkey Counties).
1920 Smith.
1912 Warren.
1911 Wayne.
1913 Wilkinson.
1912 Winston.
1901 Yazoo Area (parts of Yazoo, Sharkey and Issaquena Counties).

MISSOURI
(County and Area Projects)

1921 Andrew.
1909 Atchison.
1916 Barry.
1912 Barton.
1908 Bates.
1915 Buchanan.
1921 Caldwell.
1916 Callaway.
1910 Cape Girardeau.
1912 Carroll.
1912 Cass.
1909 Cedar.
1918 Chariton.
1920 Cole.
1909 Cooper.
1905 Crawford.
1914 De Kalb.
1914 Dunklin.
1911 Franklin.
1913 Greene.
1914 Grundy.
1914 Harrison.
1902 Howell.
1910 Jackson.
1914 Johnson.
1917 Knox.
1911 Laclede.
1920 Lafayette.
1923 Lawrence.
1917 Lincoln.
1911 Macon.
1910 Marion.
1912 Miller.
1921 Mississippi.
1915 Newton.
1913 Nodaway.
1904 O'Fallon Area (parts of St. Charles and Warren Counties).
1910 Pemiscot.
1913 Perry.
1914 Pettis.
1912 Pike.
1911 Platte.
1926 Polk.
1906 Putnam.
1913 Ralls.
1922 Ray.
1918 Reynolds.
1915 Ripley.
1918 St. Francois.
1919 St. Louis.
1904 Saline.
1905 Scotland.
1903 Shelby.
1912 Stoddard.
1917 Texas.
1904 Webster.

MONTANA
(Area Projects)

1902 Billings Area (parts of Yellowstone and Stillwater Counties).
1914 Bitterroot Valley Area (parts of Missoula and Ravalli Counties).
1931 Gallatin Valley Area (part of Gallatin County).*
1929 Lower Flathead Valley Area (parts of Lake, Missoula, and Sanders Counties).
1932 Lower Yellowstone Area (parts of Richland, Dawson, Wibaux, and Prairie Counties).*
1928 Milk River Area (parts of Hill, Blaine, Phillips, and Valley Counties)

NEBRASKA
(County Projects)

1923 Adams.
1921 Antelope.
1919 Banner.
1921 Boone.
1916 Box Butte.
1933 Boyd.*
1933 Brown.*
1924 Buffalo.
1922 Burt.
1924 Butler.
1913 Cass.
1928 Cedar.
1917 Chase.
1918 Cheyenne.
1927 Clay.
1930 Colfax.
1922 Cuming.
1926 Custer.
1919 Dakota.
1915 Dawes.
1922 Dawson.
1921 Deuel.
1929 Dixon.
1916 Dodge.
1913 Douglas.
1931 Dundy.
1916 Fillmore.
1926 Franklin.
1930 Furnas.
1914 Gage.
1924 Garden.
1933 Greeley.*
1916 Hall.
1927 Hamilton.
1930 Harlan.
1930 Hitchcock.
1932 Holt.*
1920 Howard.
1921 Jefferson.
1920 Johnson.
1923 Kearney.
1926 Keith.
1933 Keyapaha.*
1916 Kimball.
1930 Knox.
1906 Lancaster.
1926 Lincoln.
1920 Madison.
1922 Merrick.
1917 Morrill.
1922 Nance.
1914 Nemaha.
1925 Nuckolls
1912 Otoe.
1920 Pawnee.
1921 Perkins.
1917 Phelps.
1928 Pierce.
1923 Platte.
1915 Polk.
1919 Redwillow.
1915 Richardson.
1932 Rock.*
1928 Saline.
1905 Sarpy.
1913 Saunders.
1913 Scotts Bluff.
1914 Seward.
1918 Sheridan.
1931 Sherman.
1919 Sioux.
1929 Stanton.
1927 Thayer.
1914 Thurston.
1932 Valley.*
1915 Washington.
1917 Wayne.
1923 Webster.
1933 Wheeler.*
1928 York.

NEVADA
(Area Projects)

1909 Fallon Area (parts of Churchill and Lyon Counties).
1923 Las Vegas Area (part of Clark County).
1923 Moapa Valley Area (part of Clark County).

NEW HAMPSHIRE
(County and Area Projects)

1906 Merrimack.
1909 Nashua Area (part of Hillsboro County).

NEW JERSEY
(Area Projects)

1917 Belvidere Area (parts of Hunterdon, Warren, and adjoining Counties).
1925 Bergen Area (Bergen, Hudson, Essex, and parts of adjoining Counties).
1919 Bernardsville Area (parts of Morris, Somerset, and adjoining Counties).
1926 Camden Area (Camden County and parts of Burlington, Gloucester, and adjoining Counties).
1919 Chatsworth Area (parts of Ocean, Burlington, and adjoining Counties).
1927 Freehold Area (parts of Monmouth and Middlesex Counties).
1917 Millville Area (Cape May, and parts of Atlantic, Cumberland, and Salem Counties).
1923 Salem Area (parts of Salem, Gloucester, and Cumberland Counties).
1911 Sussex Area (Sussex and parts of adjoining Counties).
1921 Trenton Area (parts of Mercer and adjoining Counties).

NEW MEXICO
(Area Projects)

1928 Deming Area (part of Luna County).
1930 Fort Sumner Area (part of De Baca County).
1932 Lovington Area (part of Lea County).*
1912 Mesilla Valley Area (part of Dona Ana County).
1912 Middle Rio Grande Valley Area (parts of Bernalillo, Sandoval, Socorro, and Valencia Counties).
1899 Pecos Valley Area, Carlsbad sheet (part of Eddy County).
1930 Rincon Area (parts of Sierra and Dona Ana Counties).
1933 Roswell Area (part of Chaves County).*
1929 Socorro and Rio Puerco Areas (parts of Socorro County).

NEW YORK
(County and Area Projects)

1932 Broome.*
1922 Cayuga.
1914 Chautauqua.
1932 Chemung.*
1918 Chenango.
1914 Clinton.
1923 Columbia.
1916 Cortland.
1930 Delaware.
1907 Dutchess.
1929 Erie.
1922 Genesee.
1923 Herkimer.
1911 Jefferson.
1908 Livingston.
1906 Madison.
1933 Monroe.*
1908 Montgomery.
1928 Nassau and Suffolk Counties.
1906 Niagara.
1913 Oneida.
1910 Ontario.
1912 Orange.
1932 Orleans.*
1917 Oswego.
1932 Rensselaer.*
1925 St. Lawrence.
1917 Saratoga.
1915 Schoharie.
1931 Steuben.
1903 Syracuse Area (part of Onondaga County.)
1920 Tompkins.
1909 Washington.
1919 Wayne.
1919 White Plains Area (Putnam, Rockland, and Westchester Counties).
1933 Wyoming.*
1916 Yates.
1904 Vergennes Area, Vermont (parts of Essex and Warren Counties).

NORTH CAROLINA
(County and Area Projects)

1901 Alamance.
1915 Alleghany.
1915 Anson.
1912 Ashe.
1917 Beaufort.
1918 Bertie.
1914 Bladen.
1932 Brunswick.*
1920 Buncombe.
1926 Burke.
1910 Cabarrus.
1917 Caldwell.
1923 Camden and Currituck.
1908 Caswell.
1933 Chatham.*
1921 Cherokee.
1906 Chowan.
1916 Cleveland.
1915 Columbus.
1929 Craven.
1922 Cumberland.
1915 Davidson.
1927 Davie.
1905 Duplin.
1920 Durham.
1907 Edgecombe.
1913 Forsyth.
1931 Franklin.*
1909 Gaston.
1929 Gates.
1910 Granville.
1924 Greene.
1920 Guilford.
1916 Halifax.
1916 Harnett.
1922 Haywood.
1907 Henderson.
1916 Hertford.
1918 Hoke.
1911 Johnston.
1933 Jones.*
1909 Lake Mattamuskeet Area (part of Hyde County).
1933 Lee.*
1927 Lenoir.
1914 Lincoln.
1929 Macon.
1928 Martin.
1910 Mecklenburg.
1930 Montgomery.
1919 Moore.
1902 Mount Mitchell Area (parts of Yancey, Mitchell, McDowell, and Madison Counties).
1926 Nash.
1906 New Hanover.
1925 Northampton.
1921 Onslow.
1918 Orange.
1912 Pender.
1905 Perquimans and Pasquotank.
1928 Person.
1909 Pitt.
1923 Polk.
1913 Randolph.
1911 Richmond.
1908 Robeson.
1926 Rockingham.
1914 Rowan.
1924 Rutherford.
1923 Sampson.
1909 Scotland.
1916 Stanly.
1932 Surry.*
1906 Transylvania.
1920 Tyrrell.
1914 Union.
1918 Vance.
1914 Wake.
1932 Washington.*
1928 Watauga.
1915 Wayne.
1918 Wilkes.
1925 Wilson.
1924 Yadkin.

NORTH DAKOTA
(County and Area Projects)

1912 Barnes.
1915 Bottineau.
1904 Cando Area (part of Towner County).
1905 Carrington Area (parts of Foster and Griggs Counties).
1924 Cass.
1914 Dickey.
1902 Grand Forks Area (part of Grand Forks County).
1914 La Moure.
1932 Lower Yellowstone Valley Area, Montana (part of McKenzie County).*
1921 McHenry.
1933 McKenzie.*
1907 Morton Area (parts of Grant, Adams, and Hettinger Counties).
1906 Ransom.
1908 Richland.
1917 Sargent.
1918 Traill.
1906 Williston Area (part of Williams County).

* Indicates areas surveyed, for which the report has not ye tbeen published.

OHIO

(County and Area Projects)

1932 Adams.*
1903 Ashtabula Area (part of Ashtabula County).
1932 Athens.*
1909 Auglaize.
1927 Belmont.
1930 Brown.*
1927 Butler.
1923 Clermont.
1905 Cleveland Area (parts of Cuyahoga, Lorain, Medina, and Summit Counties).
1902 Columbus Area (parts of Fairfield, Franklin, Madison, and Pickaway Counties).
1904 Coshocton.
1922 Fulton.
1915 Geauga.
1915 Hamilton.
1925 Lake.
1930 Licking.*
1933 Logan.*
1931 Madison.*
1917 Mahoning.
1916 Marion.
1906 Meigs.
1916 Miami.
1900 Montgomery.
1925 Muskingum.
1928 Ottawa.
1914 Paulding.
1914 Portage.
1930 Putnam.*
1917 Sandusky.
1933 Scioto.*
1913 Stark.
1914 Trumbull.
1933 Vinton.*
1926 Washington.
1905 Westerville Area (parts of Delaware Franklin, Madison, and Union Counties)
1904 Wooster Area (parts of Medina, Summit and Wayne Counties).

OKLAHOMA

County and Area Projects)

1933 Alfalfa.*
1914 Bryan.
1917 Canadian.
1933 Carter.*
1931 Craig.*
1931 Grant.*
1932 Greer.*
1915 Kay.
1931 Kiowa.*
1931 Le Flore.*
1933 McIntosh.*
1932 Mayes.*
1913 Muskogee.
1906 Oklahoma.
1916 Payne.
1931 Pittsburg.*
1914 Roger Mills.
1930 Texas.*
1930 Tillman.*
1906 Tishomingo Area (parts of Johnston and Marshall Counties).
1932 Woodward.*

OREGON

(County and Area Projects)

1903 Baker City Area (parts of Baker and Union Counties).
1920 Benton.
1921 Clackamas.
1929 Columbia.
1925 Eugene Area (part of Lane County).
1926 Grande Ronde Valley Area (part of Union County).
1912 Hood River-White Salmon Area (part of Hood River County).
1919 Josephine.
1908 Klamath Reclamation Project (part of Klamath County).
1924 Linn.
1927 Marion.
1909 Marshfield Area (parts of Coos and Curry Counties).
1911 Medford Area (part of Jackson County).
1919 Multnomah.
1922 Polk.
1919 Washington.
1917 Yamhill.

PENNSYLVANIA

(County and Area Projects)

1904 Adams.
1932 Armstrong.*
1911 Bedford.
1909 Berks.
1915 Blair.
1911 Bradford.
1915 Cambria.
1908 Center.
1905 Chester.
1916 Clearfield.
1910 Erie.
1932 Franklin.*
1921 Greene.
1931 Indiana.*
1914 Lancaster.
1901 Lebanon Area (parts of Dauphin and Lebanon Counties).
1912 Lehigh.
1903 Lock Haven Area (part of Clinton County).
1923 Lycoming.
1917 Mercer.
1905 Montgomery.
1929 Tioga.
1910 Washington.
1932 Wayne.*
1929 Wyoming.
1912 York.

RHODE ISLAND

1904 Entire State.

SOUTH CAROLINA

(County and Area Projects)

1932 Abbeville.*
1909 Anderson.
1913 Bamberg.
1912 Barnwell.
1916 Berkeley.
1904 Charleston Area (part of Charleston County).
1905 Cherokee.
1912 Chester.
1914 Chesterfield.
1910 Clarendon.
1902 Darlington.
1931 Dillon.*
1915 Dorchester.
1911 Fairfield.
1914 Florence.
1911 Georgetown.
1921 Greenville.
1929 Greenwood.
1915 Hampton.
1918 Horry.
1919 Kershaw.
1904 Lancaster.
1907 Lee.
1922 Lexington.
1917 Marlboro.
1918 Newberry.
1907 Oconee.
1913 Orangeburg.
1916 Richland.
1909 Saluda.
1921 Spartanburg.
1907 Sumter.
1913 Union.
1928 Williamsburg.
1905 York.

SOUTH DAKOTA

(County and Area Projects)

1920 Beadle.
1907 Belle Fourche Area (parts of Butte and Meade Counties).
1903 Brookings Area (part of Brookings County).
1925 Brown.
1923 Douglas.
1922 Grant.
1925 Hyde.
1921 McCook.
1926 Moody.
1921 Union.
1923 Walworth.

TENNESSEE

(County and Area Projects)

1908 Coffee.
1903 Davidson.
1923 Dickson.
1907 Giles.
1906 Grainger.
1904 Greeneville Area (parts of Greene, Hawkins, Cocke, and Sullivan Counties).
1926 Hardin.
1905 Henderson.
1922 Henry.
1913 Jackson.
1904 Lawrence.
1906 Madison.
1923 Maury.
1919 Meigs.
1901 Montgomery.
1908 Overton.
1903 Pikeville Area (parts of Bledsoe, Cumberland, Rhea, and Van Buren Counties).
1912 Putnam.
1912 Robertson.
1916 Shelby.
1909 Sumner.

TEXAS

(County and Area Projects)

1904 Anderson.
1912 Archer.
1904 Austin Area (parts of Caldwell, Hays, Travis, and Williamson Counties).
1907 Bastrop.
1932 Bee.*
1916 Bell.
1918 Bowie.
1902 Brazoria Area (part of Brazoria County).
1914 Brazos.
1923 Cameron.
1908 Camp.
1933 Cass.*
1922 Coleman.
1930 Collin.
1907 Cooper Area (Delta and part of Lamar Counties).
1908 Corpus Christi Area (part of Nueces County).
1920 Dallas.
1918 Denton.
1922 Dickens.
1916 Eastland.
1910 Ellis.
1920 Erath.
1932 Falls.*

* Indicates areas surveyed, for which the report has not yet been published.

TEXAS—Continued

1908 Franklin.
1918 Freestone.
1929 Frio.
1930 Galveston.*
1909 Grayson.
1932 Hardeman.*
1922 Harris.
1912 Harrison.
1923 Henderson.
1906 Henderson Area (part of Rusk County).
1925 Hidalgo.
1905 Houston.
1903 Jacksonville Area (part of Cherokee County).
1913 Jefferson.
1906 Laredo Area (part of Webb County).
1905 Lavaca.
1905 Lee.
1917 Lubbock.
1903 Lufkin Area (part of Angelina County).
1928 Midland.
1925 Milam.
1909 Morris.
1925 Nacogdoches.
1926 Navarro.
1903 Paris Area (part of Lamar County).
1930 Polk.*
1929 Potter.
1930 Randall.*
1919 Red River.
1922 Reeves.
1907 Robertson.
1923 Rockwall.
1904 San Antonio Area (part of Bexar County).
1906 San Marcos Area (parts of Caldwell, Guadalupe, and Hays Counties).
1916 San Saba.
1931 Scurry.*
1915 Smith.
1920 Tarrant.
1915 Taylor.
1909 Titus.
1928 Van Zandt.
1902 Vernon Area (part of Wilbarger County).
1927 Victoria.
1905 Waco Area (parts of Bosque and McLennan Counties).
1913 Washington.
1932 Wheeler.*
1924 Wichita.
1926 Willacy.
1901 Willis Area (part of Montgomery County).
1907 Wilson.
1903 Woodville Area (part of Tyler County).
1912 Mesilla Valley Area, New Mexico (part of El Paso County).

UTAH

(Area Projects)

1920 Ashley Valley Area (part of Uintah County).
1904 Bear River Area (part of Cache County).
1913 Cache Valley Area (part of Cache County).
1919 Delta Area (part of Millard County).
1903 Provo Area (part of Utah County.)
1899 Salt Lake Valley Area (part of Salt Lake and Davis Counties).
1900 Sevier Valley Area (parts of Sanpete and Sevier Counties).
1921 Uinta River Valley Area (part of Uintah County).
1900 Weber Area (parts of Box Elder, Davis, and Weber Counties).

VERMONT

(County and Area Projects)

1904 Vergennes Area (parts of Addison and Rutland Counties).
1916 Windsor.

VIRGINIA

(County and Area Projects)

1917 Accomac and Northampton.
1902 Albemarle Area (parts of Albemarle, Buckingham, Greene, Augusta, Nelson, Page, and Rockingham Counties).
1904 Appomattox.
1932 Augusta.*
1901 Bedford Area (parts of Bedford, Botetourt, Franklin, and Roanoke Counties).
1909 Campbell.
1906 Chesterfield.
1915 Fairfax and Alexandria.
1914 Frederick.
1930 Grayson.
1905 Hanover.
1913 Henrico.
1903 Leesburg Area (part of Loudoun County).
1905 Louisa.
1907 Montgomery.
1932 Nansemond.*
1903 Norfolk Area (parts of Nansemond, Norfolk, and Princess Anne Counties).
1927 Orange.
1918 Pittsylvania.
1901 Prince Edward Area (parts of Amelia, Charlotte, Lunenburg, Nottoway, Cumberland, and Prince Edward Counties).
1931 Rockbridge.
1933 Southampton.*
1905 Yorktown area (Elizabeth City, Gloucester, James City, Warwick, and York Counties).

WASHINGTON

(County and Area Projects)

1907 Bellingham Area (part of Whatcom County).
1916 Benton.
1905 Everett Area (part of Snohomish County).
1914 Franklin.
1905 Island.
1911 Quincy Area (parts of Grant, Adams, and Kittitas Counties).
1917 Spokane.
1913 Stevens.
1902 Walla Walla Area (part of Walla Walla County).
1918 Wenatchee Area (part of Chelan County).
1901 Yakima Area (part of Yakima County).
1912 Hood River-White Salmon Area, Oregon (part of Klickitat and Skamania Counties).

WEST VIRGINIA

(County and Area Projects)

1917 Barbour and Upshur.
1913 Boone.
1918 Braxton and Clay.
1910 Clarksburg Area (Harrison and Doddridge Counties).
1919 Fayette.
1922 Grant and Mineral.
1927 Hampshire.
1930 Hardy and Pendleton.
1911 Huntington Area (Cabell, Lincoln, and Wayne Counties).
1916 Jefferson, Berkeley, and Morgan.
1912 Kanawha.
1915 Lewis and Gilmer.
1913 Logan and Mingo.
1914 McDowell and Wyoming.
1923 Mercer.
1907 Middlebourne Area (Marshall, Tyler, and Wetzel Counties).
1925 Monroe.
1911 Morgantown Area (Marion, Monongalia, and Taylor Counties).
1920 Nicholas.
1908 Parkersburg Area (Pleasants, Ritchie, and Wood Counties).
1933 Pocahontas.*
1910 Point Pleasant Area (Jackson, Mason, and Putnam Counties).
1912 Preston.
1914 Raleigh.
1931 Randolph.*
1909 Spencer Area (Calhoun, Roane, and Wirt Counties).
1924 Summers.
1921 Tucker.
1918 Webster.
1906 Wheeling Area (Brooke, Hancock, and Ohio Counties).

WISCONSIN

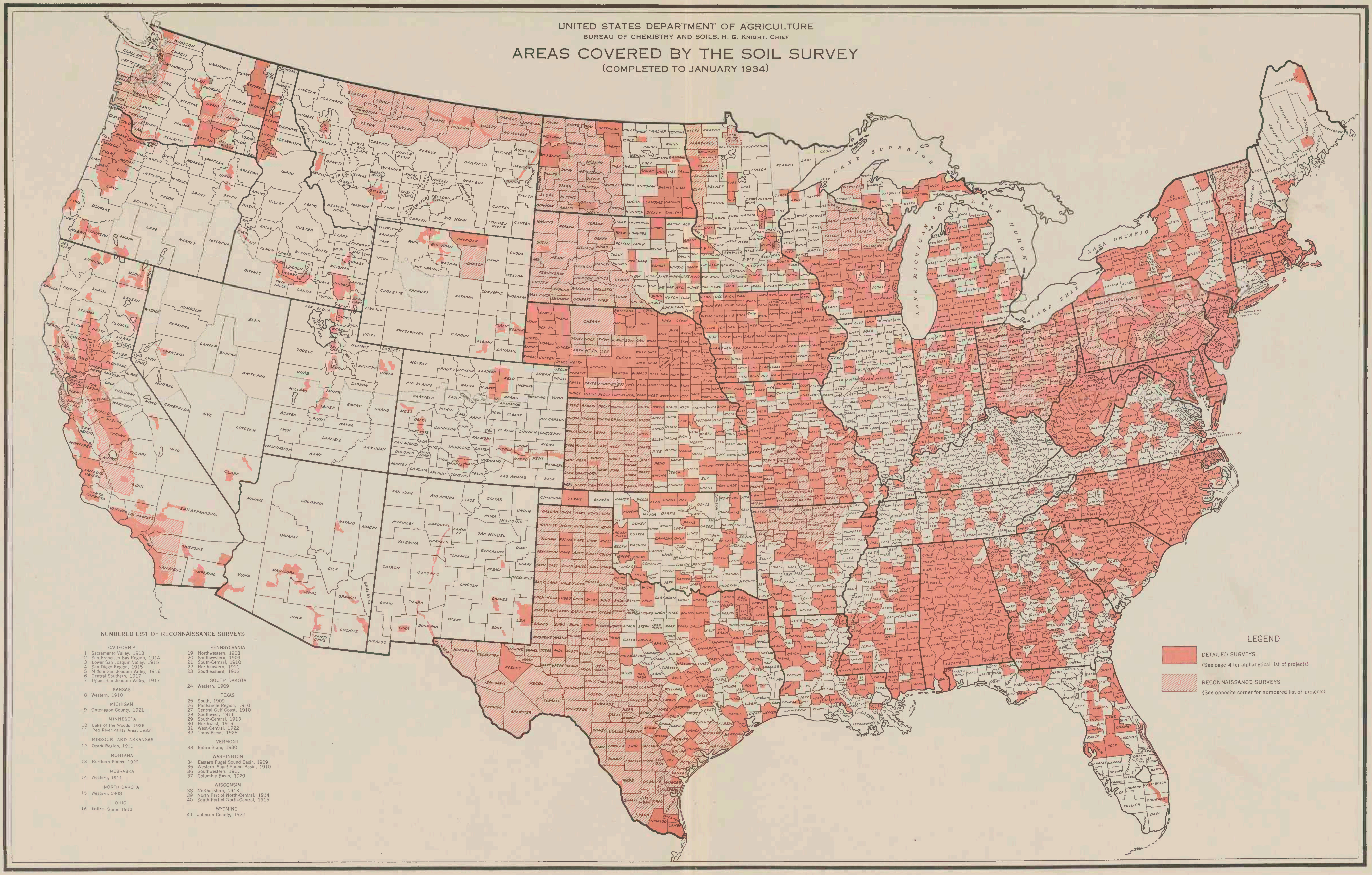
(County and Area Projects)

1920 Adams.
1910 Bayfield Area (parts of Bayfield and Ashland Counties).
1929 Brown.
1913 Buffalo.
1925 Calumet.
1911 Columbia.
1930 Crawford.
1913 Dane.
1916 Door.
1911 Fond du Lac.
1922 Green.
1922 Green Lake.
1910 Iowa.
1918 Jackson.
1912 Jefferson.
1911 Juneau.
1919 Kenosha and Racine.
1911 Kewaunee.
1911 La Crosse.
1926 Manitowoc.
1916 Milwaukee.
1923 Monroe.
1918 Outagamie.
1923 Pierce.
1915 Portage.
1917 Rock.
1925 Sauk.
1924 Sheboygan.
1904 Superior Area (part of Douglas County).
1927 Trempealeau.
1928 Vernon.
1920 Walworth.
1921 Washington and Ozaukee.
1910 Waukesha.
1917 Waupaca.
1909 Waushara.
1927 Winnebago.
1915 Wood.
1905 Carlton Area, Minnesota (part of Douglas County).

WYOMING

(Area Projects)

1928 Basin Area (parts of Big Horn, Washakie, and Park Counties).
1917 Fort Laramie Area (part of Goshen County).
1903 Laramie Area (part of Albany County).
1932 Sheridan County.*
1927 Shoshone Area (part of Park and Big Horn Counties).
1926 Wheatland Area (part of Platte County).


UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF CHEMISTRY AND SOILS, H. G. KNIGHT, CHIEF
AREAS COVERED BY THE SOIL SURVEY
(COMPLETED TO JANUARY 1934)
LEGEND
DETAILED SURVEYS
(See page 4 for alphabetical list of projects)
RECONNAISSANCE SURVEYS
(See opposite corner for numbered list of projects)
NUMBERED LIST OF RECONNAISSANCE SURVEYS
CALIFORNIA
1 Sacramento Valley, 1913
2 San Francisco Bay Region, 1914
3 Lower San Joaquin Valley, 1915
4 San Diego Region, 1915
5 Middle San Joaquin Valley, 1916
6 Central Southern, 1917
7 Upper San Joaquin Valley, 1917
KANSAS
8 Western, 1910
MICHIGAN
9 Ontonagon County, 1921
MINNESOTA
10 Lake of the Woods, 1926
11 Red River Valley Area, 1933
MISSOURI AND ARKANSAS
12 Ozark Region, 1911
MONTANA
13 Northern Plains, 1929
NEBRASKA
14 Western, 1911
NORTH DAKOTA
15 Western, 1908
OHIO
16 Entire State, 1912
PENNSYLVANIA
19 Northwestern, 1908
20 Southwestern, 1909
21 South-Central, 1910
22 Northeastern, 1911
23 Southeastern, 1912
SOUTH DAKOTA
24 Western, 1909
TEXAS
25 South, 1909
26 Panhandle Region, 1910
27 Central Gulf Coast, 1910
28 Southwest, 1911
29 South-Central, 1913
30 Northwest, 1919
31 West-Central, 1922
32 Trans-Pecos, 1928
VERMONT
33 Entire State, 1930
WASHINGTON
34 Eastern Puget Sound Basin, 1909
35 Western Puget Sound Basin, 1910
36 Southwestern, 1911
37 Columbia Basin, 1929
WISCONSIN
38 Northeastern, 1913
39 North Part of North-Central, 1914
40 South Part of North-Central, 1915
WYOMING
41 Johnson County, 1931

CONTENTS

SOILS OF THE UNITED STATES

INTRODUCTION

Soils are the products of the environmental conditions under which they have developed or are developing. These conditions in turn are the products of geologic, topographic, physiographic, climatic, and biologic factors.

The range of differences in environmental conditions within the United States is wide. This is due not only to the great area included, but also to the large number of possible combinations of environmental factors. Of the factors named, the climatic and biologic are active or dynamic and constitute the forces operating in any given spot in developing the soil. The others are passive and accelerate. retard, or modify in some other way the action of the dynamic factors. Any given association of environmental factors producing an environment would occupy, theoretically, a point only on the earth's surface, since in general each factor has a different strength of expression or a slight difference in character in different localities. In the practical consideration of environments as soil-building agents, however, a range in strength of expression or of character of each factor is accepted as a unit rather than a single absolute value. An association of these value-ranging units, producing an environment, will occupy an *area* rather than a *point*.

Although the number of possible environmental unit areas is large, many individual units extend over large areas. This is fortunate, since the expression of these conditions in terms of organic life and of that group of bodies, the soils, which are neither wholly organic nor wholly inorganic, may therefore be studied over large areas. The occurrence of similar physical conditions over large areas facilitates the study of the relationship of these conditions to the character of the soils, plants, and animals existing and developing under their influences. The physical conditions in the United States offer unusual advantages for the study of the relation of organic life and of soils to the physical environment.

Notwithstanding this inviting condition, soils as such were not studied in the United States until about the beginning of the twentieth century. The study of soils, as such, refers to the study of the genesis, the morphology, the characteristics in general of soils in the situations where they are developing or have developed, along with a study of their relation to the environment in which the development is taking place. Reference is not made to the collection of material from the soil without a study of its characteristics in place and the subjection of this material to various tests under controlled conditions in the laboratory.

SOILS AND PARENT MATERIAL

All soils go through a series of changes. At first, when they begin their "life," they consist of freshly accumulated rock material in small particles which are called, according to their various sizes, gravel, sand, silt, and clay.

Changes begin at once, and in course of time, if the surface material is not moved away and new underlying material exposed on which soil-making changes must be begun anew, the upper part of this layer of rock waste becomes so greatly changed that its characteristics are entirely different from the still unchanged material lying beneath it. This changed layer ranges in thickness from a mere film to several feet, depending on time, strength of forces, and resistance. When its characteristics have become well defined it is called a mature or well-developed soil.

The upper or changed layer is the *true soil*. The unchanged or but slightly changed deeper material, usually unconsolidated, is disintegrated rock material which may have originated in the locality where it now lies through the disintegration of consolidated rocks or may have originated through disintegration in some other spot, being later brought to its present position by water, ice, or wind and deposited as unconsolidated rock débris. It is generally true that the soil itself, or the true soil, has been made of material like that which underlies it. This underlying material is often called the *parent material* or *source material* of the soil. The layer of this material is usually designated in soil literature as the C horizon.

The true soil is usually designated as the solum (*7*)[1] and is usually separated into two parts, an upper part called horizon A, and a lower called horizon B.[2] The true soil may be defined as follows:

The soil consists of the outer layer of the earth's crust, usually unconsolidated, ranging in thickness from a mere film to a maximum of somewhat more than 10 feet, which differs from the material beneath it, also usually unconsolidated, in color, structure, texture, physical constitution, chemical composition, biological characteristics, probably in chemical processes, in reaction, and in morphology.

SOIL CLASSIFICATION

GENERAL CONSIDERATIONS

The study of any series of bodies of any kind begins, especially when the study is assuming the inductive form, with the accumulation of knowledge regarding their characteristics. It concerns the critical examination, through the senses or by simple experimental means, of their characteristics. Such work can not go very far before it becomes necessary to make some attempt to classify the results. Classification as such is not a means of increasing knowledge and can not be defined in itself as research. It is carried out as a convenience for the purpose of enabling one to obtain a comprehensive grasp of the nature of a great body of material and of the interrelationships of the various things studied. The first step consists of the creation, by definition in terms of characteristics, of units. These units may be simple or they may be compound, in the latter case capable of further subdivision into subunits. In the former case they may be based on the recognition of all the characteristics by which such bodies, up to the time of definition, are known to be characterized, constituting, for the time being at least, the simplest possible unit, not subject to further differentiation. These may be combined into larger units. In either case the broad study of the objects under consideration begins with the acquisition of knowledge of their general characteristics and the creation of units by definition based on it.

In order that soils may be classified, therefore, sufficient knowledge of soil characteristics must have been accumulated to make possible the definition of units. Historically, however, this has not been the course through which the definition of soil units has passed. Until within the preceding half century soil units were defined on a basis other than that of their characteristics. This was done because of the lack of knowledge of soil characteristics and the existence of a certain amount of knowledge regarding their relation to geological formations. On the basis of this relationship soil units, of a kind, were defined and classifications built up. Such classifications were not based on soil characteristics but on those of geological bodies from which the soils were developed. In this paper the classification is based entirely on the features of the soils themselves, including that of the parent materials. There are sound reasons for the use of the latter basis rather than the former. The latter is based on definite knowledge of the bodies concerned, whereas the former is indirect and has no necessary relationship to the features of the soils classified. The accumulated knowledge of soil characteristics now available shows clearly that there is no close relationship between the most important characteristics of soils and those of the geological formations from which they have developed. Such relationships as exist are of subordinate importance. Soils as soils can not be classified until sufficient knowledge of their characteristics has been accumulated to make it possible to define and classify them on the basis of their characteristics.

To define and classify soils under these circumstances on the basis of their relation to geology, climate, natural vegetation, or crops can be justified only as a temporary expedient. This stage in soil investigation has been passed. It has become possible, and therefore obligatory, in a scientific sense at least, to define and classify soils on the basis of the soils themselves.

SIZE GROUPS OF SOIL MATERIALS

The most evident characteristic of soils, probably the one most universally noticed by everyone, is the coarseness or fineness of the material of which they are composed. This material ranges rather widely in the size (diameter) of the particles of which it consists and in the proportions of the various-sized particles present.

The particles of mineral material found in soils range in size from large stones to those too small to be seen with a microscope. Those particles larger than 2 millimeters in diameter are roughly classified as gravel, cobbles, or stones, but no definite limits have been given to each.

It is evident that it is wholly impracticable in defining soils on the basis of the sizes of the particles of which they are composed, to recognize every difference, however small, as a basis for defining a different soil unit. This difficulty is avoided by grouping all soil particles into a number of size groups each with a given range and using each of these groups as a size unit in defining texture. Each of the size groups is called a class of soil material.

The material made up of particles smaller than 2 millimeters is divided, in the United States, into four general classes, according to the range in diameter of the particles. In Europe, the particle-size limits of each group are slightly different from those in the United States, but the difference is not highly important and need not be discussed here (*2*). Those particles ranging in size from 1 to 2 millimeters in diameter are called fine gravel; those ranging from 1 millimeter to 0.05 millimeter are called sand; those ranging between 0.05 and 0.005 millimeters are called silt; and all particles smaller in diameter than 0.005 millimeter are called clay.

The Sand group is subdivided into coarse, medium, fine, and very fine sand; the first including particles ranging in diameter between 1 and 0.5 millimeter; the second, those ranging between 0.5 and 0.25 millimeter; the third, those ranging between 0.25 and 0.1 millimeter, and the fourth, those between 0.1 and 0.05 millimeter.

That characteristic of soils dependent on the relative proportions of the various-sized particles present is known as texture. A soil is fine or coarse in texture according to the relative proportions of fine and coarse particles present in its material. Since the percentage of organic matter in soils, except in rare cases, is small, rarely amounting to more than 10 per cent, and in agricultural soils usually less than half this amount, it is evident that the textures of soils depend mainly on the mineral material of which they are composed.

When the organic matter present is in a thoroughly decomposed condition, the only condition in which it constitutes an important part of the soil, it is extremely fine in grain and belongs, therefore, in the same size group as the clays of the mineral part of the soil. It becomes, therefore, unnecessary to attempt any separate classification of this material.

DEFINITION AND NOMENCLATURE OF TEXTURE GROUPS

No important soil is made up wholly of any one group of particles. Experience gained in the study of soils over the greater part of the earth's surface shows that soils consist of mixtures of particles belonging to two or more of these groups.

The recognition of this fact made it necessary, when the work of soil mapping was taken up in earnest, to group the entire range of possible combinations of the several soil material classes into a limited number of units and define each in terms of the proportions present of the several classes of material. It became necessary to give each unit a name, thus avoiding the necessity of describing each unit on referring to it. Six principal texture groups were established, to which the names sands, sandy loams, loams, silt loams, clay loams, and clays were given, each of these being further divided into minor subgroups, according to the sizes of the predominant sand grains and the extreme variations of silt and clay present. The principal groups are described as follows:

SANDS include all soils containing less than 20 per cent silt and clay, the rest of the material being sand.

[1] Italic numbers in parentheses refer to literature cited, p. 98.

[2] The A and B horizons, the former consisting of a surface layer from which material has been removed by soil-making forces and the latter of a layer into which material has been brought by the same forces, are more typically characteristic of the Pedalfers or humid-region soils than of the Pedocals of the subhumid and arid soils. The soil section or the series of successive layers, or horizons, from the surface downward is called the soil profile.

Coarse sands contain 35 per cent or more of fine gravel and coarse sand and less than 50 per cent of other grades of sand.

Medium sands contain 35 per cent or more of fine gravel, coarse and medium sand, and less than 50 per cent of fine or very fine sand.

Fine sands include 50 per cent or more of fine and very fine sand.

Very fine sands contain 50 per cent or more of very fine sand.

SANDY LOAMS contain from 20 to 50 per cent of silt and clay. They are designated as coarse, medium, fine, and very fine sandy loams in accordance with the predominant sand class group present. There are also gravelly loams and stonyloams.

LOAMS AND CLAYS contain 50 per cent or more of silt and clay combined.

Loams contain 20 per cent or less of clay, from 30 to 50 per cent of silt, and from 30 to 50 per cent of sand.

Silt loams contain 20 per cent or less of clay, 50 per cent or more of silt, and 30 per cent or less of other classes.

Clay loams contain from 20 to 30 per cent of clay, from 20 to 50 per cent of silt, and from 20 to 50 per cent of sand.

Clays contain 30 per cent or more of clay and 70 per cent or less of other classes.

In the practical operation of mapping soils in the field, the field man determines first the texture of the surface soil of the soil he is concerned with at the time.

Experience has shown that soils vary in texture within wide limits in the various parts of their profile between the surface and a depth of several feet. All true soils consist of a series of layers, which may differ widely in thickness and character, found in succession from the surface downward. Each layer may have a texture entirely different from that of any other. It is impossible, therefore, to designate the texture of a soil, including all its layers, by a single term. This fact has made it necessary to limit the application of the term describing the texture of a soil to one of the layers. It is manifest that the term must apply to something more than a mere surface film. It must apply, if it have any real significance as a description of the characteristics of the soil, to a layer at least a few inches in thickness. A soil may be thin or thick, but considering the soils of the world as a whole, their thickness may be described as 2 feet or more. In only relatively small areas is it less than 2 feet, and over wide areas of the world it is more, but over small areas only is the true soil more than 8 or 10 feet thick. Since the texture is not uniform throughout this entire thickness of soil, even where it is somewhat less than 2 feet thick, the name designating the texture, such as loam, is restricted, where not otherwise stated, to the texture of the surface layer only, usually to a depth of about 8 inches.

Since it is a well-known fact that even within this thickness the texture is not uniform in the natural virgin soil, it follows that the terms designative of the texture of a soil apply, unless a definite figure for thickness is given, to the plowed layer in field soil. As generally used, therefore, it refers to the texture of the material in those layers or parts of layers extending to a depth of about 8 inches when uniformly mixed. As used in the reports of the United States Soil Survey, the texture of a soil is significant in an agricultural sense, therefore, rather than in a technical sense.

From the scientific point of view alone the texture of the surface horizon is of no more significance than that of any other horizon in the soil profile. From the point of view of agricultural practice, it is more important because of the fact that cultivation of the soil rarely extends to greater depth than 8 or 10 inches, and this layer constitutes the feeding ground of a considerable part of the roots of most of the crop plants. It is also the layer to which fertilizers are applied. Because of the agricultural importance of this horizon it is given separate recognition in most western soil literature. Until a few decades ago it was the only soil horizon which was described in most soil literature and the only one to which a descriptive name was applied.

After the inauguration of the work of soil mapping in the United States, more than a quarter of a century ago, and the thorough study of soil characteristics made necessary by this work, it soon became evident that the characteristics of other horizons, as well as those of the surface horizon, demanded recognition. In detailed descriptions of the profiles or sections of soils, especially virgin soils, the thicknesses of the several horizons or subhorizons, and their respective textures, are described, but in the designation of a soil as a loam, silt loam, etc., such designation concerns the surface layer to plow depth except where otherwise stated.

In the description of the soil as a natural body, without reference to its use in agriculture, the textures of all the layers are described, but even in such a description the designation of the soil as a loam means that the texture of the surface layer is loam. The textures of the layers of a soil other than the surface layer are connoted in that part of the soil name referring to the series rather than the texture and will be discussed in considering the *series* characteristics of soils.

GROUPING OF TEXTURE UNITS INTO SERIES UNITS

The definition of soil units by texture only is a definition based on a single characteristic, and, as has been pointed out, applies to one only of the several horizons and subhorizons making up the soil. A sound classification must be based not alone on the texture but on texture and all other important characteristics of all the horizons of the soil profile. The successive horizons may differ one from another in color, texture, structure, chemical composition, and in many other respects, some of which were mentioned in the definition of a soil on page 11.

Since a difference in a single respect, and in one horizon only, of a given soil from the corresponding horizon of some other soil constitutes an important difference between the soils and establishes their separate identity, it follows that, because of the considerable number of horizons and the great number of respects in which each may vary, there must exist on the earth's surface a great number of soil individuals, even if the texture of the surface horizon be identical in all. The most common of all soil knowledge shows that the texture of the surface soil varies through a considerable range of differences, so that the individuals differentiated on this basis, added to those differentiated through the many possible combinations of the several characteristics of each of the several horizons, make the possible number of soil individuals very large.

To each soil in which the texture of the surface material to a depth of 8 inches, or of thinner horizons or subhorizons as described in each case, is uniform, a name is applied descriptive of the texture in accordance with the unit definitions of texture as described. This constitutes the final unit designation of every soil, corresponding to the species designation of plants.

To all soils whose characteristics, other than texture of the surface layer, are uniform in all respects, but in which there may be a considerable range in textures of the surface layer, some, for example, whose surface horizon texture is silt loam, others sandy loam, loam, etc., a series designation is given.

Since the grouping of soils into series is based on all characteristics other than the texture of the surface horizon and since the total number of soils is large, it is evidently impossible to designate each by a descriptive name.

In the United States it has been found most convenient, therefore, to designate each series by a geographic term which usually refers to the locality in which one or more of the soils of the series were first identified. Since the series name is a group name, including soils which differ in texture of the surface layer it is evident that the designation of a soil which is uniform throughout in all characteristics, including that of the texture of the surface horizon, must be a double designation, one part covering series characteristics, the other covering the texture of the surface horizon. For example, the expression Norfolk sandy loam, when applied to a soil, connotes, in the first or geographic part of the expression, all the characteristics of that soil except the single characteristic of the texture of the surface horizon, and is applied to a group of soils, the members of which differ one from another in the texture of the surface horizon but are alike in all other features.

The words sandy loam are descriptive of the texture of the surface horizon. The two terms, therefore, designate a soil unit. All areas of Norfolk sandy loam, wherever they may occur, are uniform in all respects, and such a soil unit is called, in the nomenclature of the Bureau of Chemistry and Soils, a soil type.[3] Since the number of textures and, therefore, the maximum possible number of texture units within a given series, cannot be great, each unit can be given a descriptive name for that part of the whole name which applies to texture of the surface soil. In a given series, therefore, we may have, for example in the Carrington series, a Carrington loam, silt loam, clay loam, clay, sandy loam, fine sandy loam, coarse sandy loam, and so on.

Very few, if any, soil series contain individuals representing all the possible textures of the surface horizon. Most soil series in the United States, however, include more than one texture individual. In most cases two or three texture individuals will include by far the greater part of the areas of any given series, the others constituting small areas of unimportant significance and usually without normal series characteristics.

The definition of soil units is a constructive creative process resulting in the establishment of entities that had no previously recognized existence. A texture unit is not a unit in the establishment of which all characteristics of the soil were taken into consideration. The establishment of a soil unit must be the result of a full consideration of all the characteristics of all the horizons throughout the soil including the C horizon, or parent material. On the other hand, a consideration of series characteristics alone, neglecting the texture of the surface horizon, could not result in the creation of a soil unit. All characteristics must be considered, and when on this basis a soil unit has been created, its designation must be a double designation consisting of the series name and the texture description.

All the soils of an area, state, continent, or even of the world, may be defined, described, or in other words isolated, individualized, or created and named in this way. The soils of the United States, so far as they have been mapped, have been mapped on this basis and no other. At one time certain so-called soil provinces were defined covering the United States, and these were used as a basis of soil definition, but it was later shown that such a basis of creation constituted an incongruous, illogical, and erroneous basis for such work, and their use was discontinued.

Notwithstanding the fact that all soils may be identified, defined, and named in the way described, it is well known by every student of soils that soils have relations to each other not expressed by such a process. The creation of units is one process; the discovery and exhibition of the interrelationship of these units is entirely another. The latter work can not be done until the first has been performed. This is evident since the relationships based on them can not be determined.

The expression of this relationship is brought about by grouping the individual soil units or soil types on the basis of some characteristic or series of characteristics common to all the individuals in each group. Such a group or series of groups constructed on the basis of a given kind or order of characteristics will constitute what may be called a category. The individual soil units will constitute the first or lowest category. The second will include the groups of the lowest order, members of each group containing a large number of features and necessarily consisting, therefore, of a small number of individual soil units. The number of units (groups) in Category II will be large but of course smaller than the number of individuals in Category I.

A third category may be constructed by grouping the groups in Category II according to some characteristic or series of characteristics. The number of groups in Category III will necessarily be smaller than in II but each group will contain a greater number of individual soil units since this number must include all existing units and therefore the same as in Categories I and II. Each group, because of its inclusion of a larger number of units than those in the groups of any lower category will be constructed necessarily on the basis of a smaller number of characteristics than those involved in any group in any lower category.

This grouping may be continued into a number of successively higher categories, each category containing a smaller number of groups than in any lower category, the final category containing a minimum of two groups the individuals in each of these groups having a smaller number of characteristics in common than are common to the groups in any lower category.

It is evident that in each of the groups of the scheme of categories as they have been sketched above each unit, except those in the very lowest category, is itself a group consisting of more than one of the units in the lowest category of the scheme. In order to release the word group for use in designating the groups of units rather than for the major groups of the scheme, the latter have been designated as categories. The scheme therefore includes a series of categories rather than a series of groups.

Any comprehensive scheme for a complete grouping or classification of soils which would bring out the relationships of the various soils in all their different degrees of kinship must include such a series of categories.

[3] A soil type as the term is used in the United States is a soil unit based on consideration of all soil characteristics and is designated by the series name and texture description, for example, Norfolk sandy loam.

The construction of a scheme of classification by categories is based on the recognition of a limited number, or a number smaller than the maximum, except in the lowest category, of all the soil features and the neglect of others, the number taken into consideration in any category depending on the comprehensiveness or inclusiveness of the groups in the category.

Such a scheme of classification or grouping is somewhat similar to the schemes of grouping of plants and animals. The soil type, with its double designation, corresponds to the plant unit with its generic and specific designation. The higher categories in the soil scheme undertake to show the broader relationships of soil units just as those in the schemes for plant and animal classification do the same thing for plants and animals.

THE CATEGORIES IN A SCHEME FOR SOIL CLASSIFICATION [4]

CATEGORY I, SOIL UNITS

Category I consists of soil type units. The general character of soil types has been described on preceding pages and needs no further description here. The category will include all soil units and is not made up of groups. It includes the maximum number of units in the scheme. The descriptions of the very great number of soil types in the United States can not be undertaken in a publication of this kind. Those already defined are described in the many detailed reports of the Soil Survey.

CATEGORY II, SOIL SERIES GROUPS

This category includes the series units. These have also been described on preceding pages and need no further description. They consist of groups of texture units, and the category therefore would include a smaller number of units than would Category I. The series units are defined on the basis of all the characteristics of the soil, except the texture of the surface horizon, including the character of the parent material.

It is manifest from what has been said on the preceding pages that each higher category must contain groups of soils, the members of each of which have a smaller number of features common to all than are common to any group in a lower category. Since the parent material is found in soils at considerable depth only and is therefore of less importance as a soil characteristic than those features lying nearer the surface, and since the grouping of soils into categories higher than that made up of series groups can be effected only through the use of a smaller number of features than are used in the latter grouping, it is evident that those characteristics determined by parent material only should be the first to be eliminated. None of the categories higher than II will contain groups based on the character of the parent material. The description of all soil series established up to the present time is too great a task to be undertaken in a publication of this kind. Those in the United States are described in the Soil Survey reports and in part in the text of this Atlas.

CATEGORY III, LOCAL ENVIRONMENT GROUPS (FAMILY GROUPS)

Category III includes groups, the units in each of which have some features in common, developed by local rather than general environmental conditions. The units in each group consist of the series groups of Category II, these being grouped into the units of Category III because the characteristic features common to the members in each are the product of local conditions, such as differences in drainage and relief; specially striking characteristics of parent material, such as the presence of high content of calcium carbonate or of sodium or other salts; parent materials made up of organic matter; or any other local condition. This category would include groups of infantile, young, and mature soils, under good drainage; the long and complex list of poor and imperfectly drained soils; peat soils; Rendzinas; salty and alkali soils; mountain meadow soils; mountain carbonate soils; and others.

CATEGORY IV, BROAD ENVIRONMENT GROUPS (GREAT SOIL GROUPS)

Category IV includes groups based on characteristics common to the soils of a large area of country in which those conditions known to produce local variations in soils, such as rapid changes in slope, in drainage conditions, in geological character, and texture of the soil materials have been reduced to a minimum, or in which these conditions are at least not the dominant ones. We are now concerned with those characteristics which have wide distribution and are presumably produced by forces having a comparable distribution. This category, therefore, is based on the features of well-drained soils developed on relatively smooth land surfaces, from materials free from large amounts of those few compounds known to have strong influence on the characteristics of soils in the early stages of their development. It may be based also on the features of soils derived from materials originally containing those compounds, but in which development has progressed far enough for the disappearance of features produced by these compounds. Our knowledge of soils is already sufficiently extensive to warrant the statement that within a given region, with few if any exceptions, the soils of a considerable part of the total area have developed free from these inhibiting influences or have reached a stage of development in which features produced by them in an earlier stage of soil development have been eliminated. Such soils are now generally recognized as normally developed soils.

A comparison of the distribution of features with that of the various factors of the geographic environment reveals that they coincide with the distribution of one or another of the important factors of a given climatic type or of natural vegetative type. For this reason they are often called climatic soil groups. A comparison of soil features with various factors of the climatic environment has shown, however, that they differ from place to place in harmony with differences of more than one of these factors. For example, it is well known that some soil features differ with differences of temperature, others with differences of moisture.

The groups of Category IV are made up of a number of related soil series. The similarity among them is a similarity of true soil or solum features but not a similarity of parent materials. The latter may consist of the most widely different geologic materials possible. The similarities, being wholly independent of the parent materials and consisting of features that can not have been present before soil development began, must therefore be the product of changes imposed on the material during the progress of soil development. They are, therefore, the product of their environment.

The groups in this category include some of the best-known, most universally recognized, and best-defined soil groups of the world, some of which were first defined by Russian pedologists. Their relation to the Russian scheme and Russian mapping is somewhat similar to that between soil series groups and mapping in the United States. Those described by the Russians do not include all known at the present time, and still others will probably be discovered in the future. They constitute the only groups of soils belonging in the higher categories to which names, more or less generally used by pedologists throughout the world, have been given.

The groups are Tundra soils, Podzols, Gray-Brown Podzolic soils, Red soils, Yellow soils, Prairie soils, Laterites, and ferruginous Laterites, Chernozems, Dark-Brown soils, Brown soils, Gray soils.

The description of the soil series included in those parts of each of the groups found in the United States will constitute the greater part of the text of this Atlas. It is unnecessary to describe them here in full, and since their differences involve several features, a short characterization is difficult. In general it may be said that the Tundra soils seem to consist largely of unweathered or very slightly weathered clays, silts, and sands, generally bluish in color and very slightly differentiated into surface soils and subsoils. Podzols are gray soils with dark-brown or rich-brown subsoils. The Gray-Brown Podzolic soils are light-brown or faintly yellowish soils with brown or faintly reddish brown heavier subsoils. The Yellow soils are pale yellow soils, gray if very sandy, with deep-yellow subsoils heavier than the surface soils. The Red soils are yellowish or reddish-yellow soils with deep-red subsoils. The Prairie soils are black or dark-brown soils with brown subsoils which are little if any heavier than the surface soils. The Chernozems are black soils with brown or reddish calcareous subsoils. The Dark-Brown soils are like Chernozems in most respects except in their surface color which is described in their name. The Gray desert soils are gray with gray, light-brown, yellowish, or reddish calcareous subsoils.

The Tundra soils occupy arctic regions as well as high mountain tops.

The Podzols lie in general in forested regions, predominantly those in which conifers constitute an important part of the vegetation. In the United States they lie mainly in northern New England and the northern lake region but occur on very sandy soils elsewhere. The Gray-Brown Podzolic soils occupy the mid-latitudes of the eastern part of the United States from the Atlantic coast westward to western Indiana. The Yellow soils occupy the sandy regions of the coastal plain from North Carolina to east Texas; the Red soils occupy the southeastern part of the United States, except the regions covered by Yellow soils; and the Prairie soils occupy the original grassland east of a line running from northwestern Minnesota to Corpus Christi, Tex. Some of the soils of the Southeastern States seem to belong to the ferruginous-Laterite group, but are merely lateritic, not yet having reached the Laterite stage.

The Lateritic soils have not been thoroughly investigated. That they exist there can be no doubt, but the groups of which they are composed, comparable in general character to the groups of the Podzolic soils, have not yet been worked out. It is apparent, however, that there are at least two groups. These may be described as aluminous-Lateritic soils and ferruginous-Lateritic soils. What their morphological characteristics are is yet unknown.

In the United States typical Chernozems, essentially like those of the Russian steppes where they were first described, seem to occur only in the mid- and north-latitude belts of the United States, in Kansas, Nebraska, and the Dakotas. On Plate 2, the Chernozem belt of the United States, running north and south across the country, is broken into a northern and a southern part. The Dark-Brown and Brown soils occupy north-south belts in the Great Plains lying successively west of the Chernozem belt, and occur also in many areas throughout the Rocky Mountain region. The four groups occupy also a series of north-south belts in eastern Washington and Oregon.

CATEGORY V, INORGANIC COLLOID COMPOSITION GROUPS

Category V includes broad groups of soils differentiated on the basis of the general composition of the products of the breaking up of the rocks in the processes of soil building. It concerns that unconsolidated inorganic material described in this publication as the parent material of the soils and more specifically the colloidal part of that material, since that is the material constituting the products of most complete breaking up of these rocks. The composition of this material differs from place to place in more or less definite relationship to differences in temperature. The presence of water, by the activity of which hydrolysis is effected, is assumed. In the far north, according to Swedish investigators, especially Dr. Olaf Tamm, the minerals of rocks have been only slightly hydrolyzed, especially since glacial times, the fine material of which the soils are made having been made fine in grain, to an important part at least, by mechanical processes. The resulting material therefore has a relatively high silica-alumina molecular ratio.

Farther southward, at least in mid-latitudes, such as the latitude of central Europe and mid-United States, hydrolytic action has been the dominant factor in rock decomposition, the resulting colloid having a silica-alumina molecular ratio approximating 1 to 2.

Still farther south, most characteristically in the Tropics, hydrolytic action, stimulated by high temperatures, has gone still farther in the breaking up of the colloids, especially in the removal of combined silica or silicate silica and the alkalies and alkaline earths, and it has produced a product in which the molecular ratio of silica to alumina is or may become 1 to 1 or lower.

The relationship of colloid composition to different temperature conditions refers specifically to such temperature changes as take place in regions of high rainfall. It is here assumed that the same relationships exist in regions of low rainfall, so far as hydrolytic decomposition of rocks has taken place. Very little is known, however, about the results of rock decomposition in regions of low rainfall.

The first group, including "soils from mechanically comminuted material" refers to soils developed in regions of very low temperatures, but it is by no means certain that the fine-grained parent materials of such soils have been developed by mechanical means. Results obtained to date do not show what proportion has

[4] See tabular arrangement of the categories, p. 14.

probably been accumulated by hydrolytic action, although Tamm states that in Sweden that material has suffered some loss of silicate silica, presumably through hydrolytic action.

It will be noticed that one of the groups in Category IV is designated as "Laterites", the term being equivalent to "Laterite soils." In Category V, however, the corresponding group includes soils from allitic (lateritic) material. One category refers to Laterite soils, the other to Laterite as parent material. The expression lateritic soils occurs extensively in soil literature, and it has been inserted here because of that fact. In the opinion of the writer of this publication, the term Laterite should be applied to the products of rock decomposition and therefore to soil material, or parent material of soils rather than to soils. It has become apparent, although not yet proved beyond question, that Laterite is geological material or parent material of soils from which more than one type or group of soils may develop. In the humid Tropics the soil developing from Laterite material seems to be Podzolic, though rarely if ever very highly podzolized for evident reasons which need not be discussed here.

It is conceivable that in the development of soils in the Tropics, a stage is passed through, which could be described as a Laterite soil stage. This is the stage in which rock decomposition has brought the surface material to the Laterite stage, but Podzolic processes have not yet had time to operate on them.

The Red soils of the southeastern part of the United States are Podzolic, if that term be defined in the long-accepted way, but they have developed on lateritic (allitic) material.

Such studies, more or less hastily carried on, as the writer of this paper has made of the soils of the Mediterranean region, indicate clearly that they are Podzolic and are developing on material somewhat allitic in composition but not yet converted into Allite.

CATEGORY VI, SOLUM COMPOSITION GROUPS

It is possible to divide or group all soils into two major groups on the basis of soil characteristics. Soil specialists have long recognized the desirability of such a grouping and expressed it by grouping soils under the terms residual and transported.

It is now recognized that this grouping is not a soil grouping but is, on the other hand, a grouping of geological materials according to the geological processes by which they were accumulated. A grouping of soils must be based on soil rather than on geological features and processes.

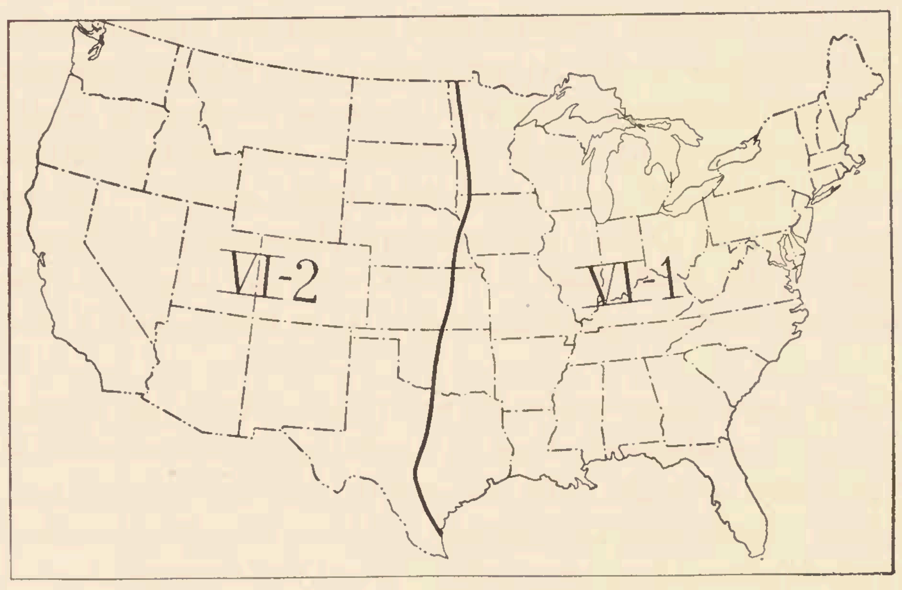


FIGURE 1.—General distribution of Pedocals (VI-2) and Pedalfers (VI-1).

It is possible to group soils into two major groups, on the basis of more than one soil feature. For example, it would be possible to group them into well-drained soils and poorly drained soils, into dark-colored soils and light-colored soils, and, as we shall see, on at least one other basis. The arguments for and against one or the other of these bases cannot be stated here. It can be stated, however, that after mature consideration of all the factors involved it has been decided that the best basis on which soils can be classified into two major groups is that of the presence, in one of the groups (the Pedocal group) of a zone of lime carbonate accumulation in some horizon or layer of the soil profile, regardless of the character or composition of the parent rock, and the absence of such accumulated material in any horizon of the soil profile in the other group (the Pedalfer group). This seems to be the most permanent and most tangible basis on which to effect this result. The line across the United States separating these two groups coincides with the western boundary of the prairies. It is shown on the outline map (fig. 1) by the heavy black line.

The grouping by categories is summarized as follows:

Category VI.	Pedalfers (VI-1)	Pedocals (VI-2)
Category V.	Soils from mechanically comminuted materials. Soils from siallitic decomposition products. Soils from allitic decomposition products.	Soils from mechanically comminuted materials.
Category IV.	Tundra. Podzols. Gray-Brown Podzolic soils. Red soils. Yellow soils. Prairie soils. Lateritic soils. Laterite soils.	Chernozems. Dark-Brown soils. Brown soils. Gray soils. Pedocalic soils of Arctic and Tropical regions.
Category III.	Groups of mature but related soil series. Swamp soils. Glei soils. Rendzinas. Alluvial soils. Immature soils on slopes. Salty soils. Alkali soils. Peat soils.	Groups of mature but related soil series. Swamp soils. Glei soils. Rendzinas. Alluvial soils. Immature soils on slopes. Salty soils. Alkali soils. Peat soils.
Category II.	Soil series.	Soil series.
Category I.	Soil units, or types.	Soil units, or types.

THE GEOGRAPHIC RELATIONSHIPS OF THE CATEGORIES

This brief description covers one possible scheme for the grouping of soils into a series of successively more and more inclusive groups. It is the scheme now in use in the Soil Survey of the Bureau of Chemistry and Soils in all cases where the discussion of soils in groups is broader or more inclusive than series groups. No insurmountable difficulty has yet been met in its practical use, but it should be borne in mind in this connection that many schemes may be constructed from which this result might be expected. The essential requirement of such a scheme is not merely that it should be workable, but that it should group soils logically according to their characteristics and should arrange the groups in such a way as to express both this relationship and their relationship to the environment in which the soils have developed. The latter can be expressed only by showing the distribution of the soils of the category groups on a map and comparing this map with maps showing the distribution of the several environmental factors, such as rainfall, temperature, humidity, natural vegetation, character of parent material, and relief.

It is possible that when knowledge concerning the groups has become much fuller than at present, their distributional relationship may be shown in all their gradations on a single complex large-scale map. At present this is not possible. The distribution in the United States of the groups in some of the categories is shown in outline in differing degrees of accuracy and fullness in maps in this report.

The small outline map (fig. 1) shows the general distribution within the United States of the two groups in Category VI. The line separating the areas of their predominant occurrence runs from northwestern Minnesota to Corpus Christi, Tex. The soils east of this line are without exception Pedalfers. West of it, both Pedocals and Pedalfers occur, though the former are dominant. The scale of the map is too small to allow their separation in detail. In general it may be said that the soils on the plains and plateaus within the region are Pedocals, and those in the mountains are mainly Pedalfers.

The Pedocalic soils, when normally developed, differ very greatly from the Pedalferic soils. They have lost a very small amount of the constituents originally present in their parent materials, and some of them have, in addition, accumulated a large amount of organic matter. Although it is true that in some cases, which may be construed as extreme, a large amount of organic matter accumulates in the Pedalferic soils, in general these soils contain a very small amount of organic matter; and while it is also true that in some of the groups of the Pedocalic soils the amount of organic matter is small, these soils in general retain a much larger proportion of the organic matter made available by the vegetation growing on them, than is true of the Pedalferic soils. It would be clearer to state, therefore, that the Pedocalic soils are rich in organic matter in all members on which a rich vegetation grows and have a low amount of organic matter in those members on which no rich vegetation grows. The amount of mineral material entirely removed from the Pedocalic soils is small.

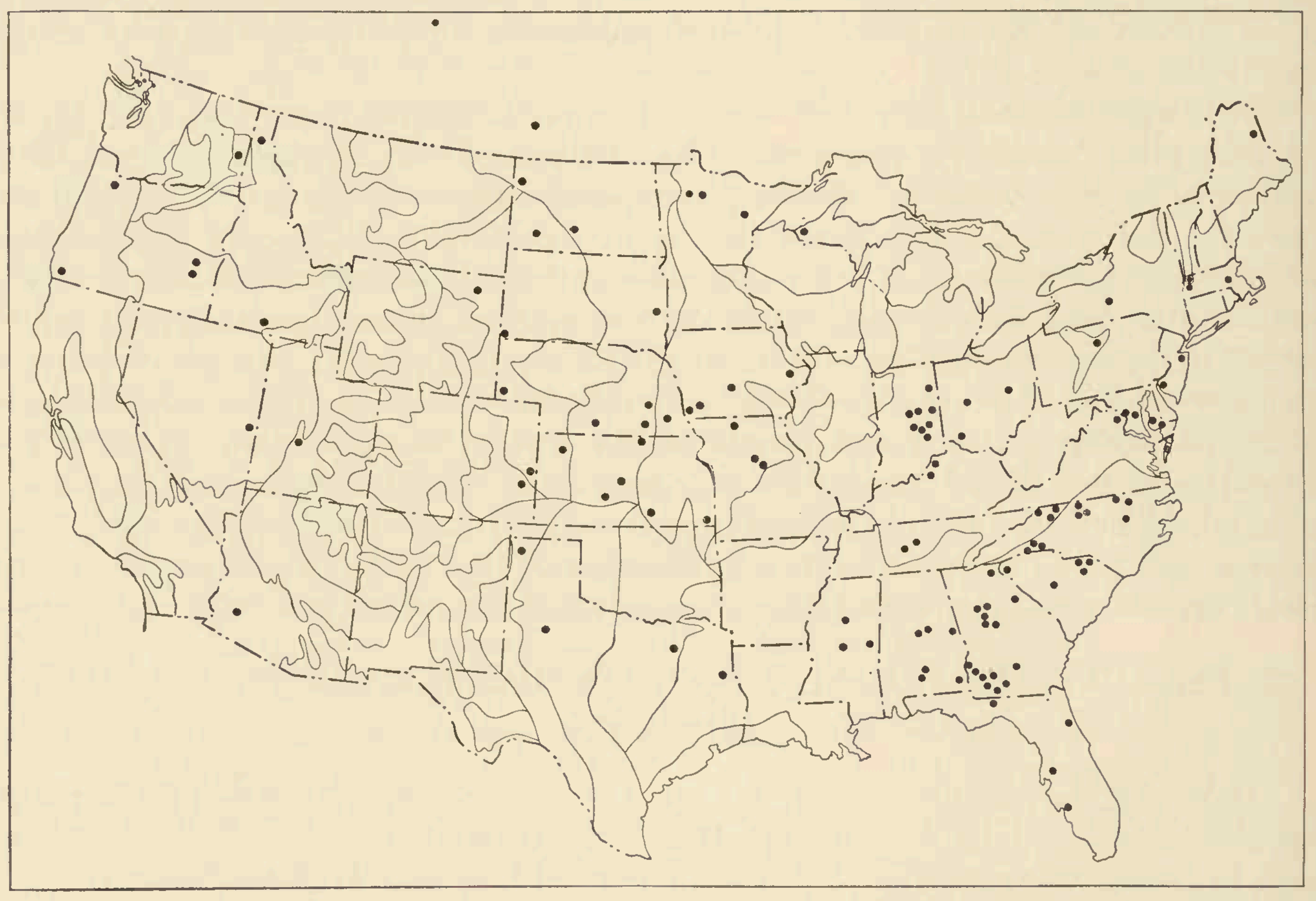


FIGURE 2.—Locations of analyzed soil profiles.

The Pedalferic soils are low in organic matter, except in one of the groups, and have lost, when mature, a considerable part of the alkalies and alkaline earths, some of the iron, and some of the silica originally present in the parent material. They are, in general, leached soils. Sesquioxides also have been shifted from one part of the solum to another. In the Lateritic soils, sesquioxides remain as the chief component.

Since the establishment of the Soil Survey many soil samples have been taken from carefully selected representative soil profiles. Only a relatively small number of these samples have been chemically analyzed. In nearly all cases mechanical analyses have been made of samples which were chemically analyzed. The locations from which the analyzed samples were taken are indicated in Figure 2.

The important differences in chemical composition between the members of the two groups is illustrated by the composition of two soils, a Pedalfer from Wayne County, Ind., and a Pedocal from Krydor, Canada. (Table 1.) Both consist of a series of successive layers from the surface downward. The two soils are different in practically all respects. In the Pedalfer the percentage of silica in the upper two layers, which constitute the A horizon, is high, and the percentages of iron oxide and alumina are low when compared with the upper two layers of the Pedocal.[5] The silica in the B horizon of the Pedalfer is low, compared with that in the A horizon, and that in the Pedocal, except in layer 1, presents a similar relationship. The iron oxide and alumina, however, in the B horizon of the Pedalfer are both high, while in the Pedocal they do not differ very greatly in the loss-free composition throughout the profile.

TABLE 1.—*Chemical composition of a Pedalfer and of a Pedocal*

A PEDALFER, WAYNE COUNTY, IND.

Sample No.	Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Loss on ignition	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
283702	A_1	3-5	[1] 80.46	0.72	3.00	7.79	0.04	0.83	0.49	1.64	1.04	0.08	0.12	3.62	99.83	0.10	------
			[2] 83.49	.75	3.11	8.09	.04	.86	.51	1.70	1.08	.08	.12	------	99.83	------	------
283703	A_2	6-9	[1] 81.58	.59	2.64	8.21	.048	.49	.30	1.79	1.14	.03	.04	2.90	99.76	.042	------
			[2] 84.00	.61	2.72	8.45	.049	.50	.31	1.84	1.17	.03	.04	------	99.72	------	------
283704	B_1	10-15	[1] 75.37	.62	4.65	11.41	.035	.51	.72	2.21	1.02	.02	.02	3.43	100.02	.032	------
			[2] 78.02	.64	4.78	11.82	.036	.53	.75	2.29	1.06	.02	.02	------	99.97	------	------
283705	B_2	16-30	[1] 69.81	.56	6.18	13.72	.032	.72	1.11	2.48	1.11	.07	.03	4.21	100.03	.038	------
			[2] 72.89	.57	6.48	14.33	.033	.75	1.16	2.59	1.16	.07	.03	------	100.03	------	------
283706	C_1	31-42	[1] 58.92	.37	3.66	9.70	.033	7.40	4.92	1.91	1.12	.08	.03	11.95	100.09	.028	3.00
			[2] 66.91	.42	4.16	11.02	.037	8.40	5.59	2.17	1.27	.09	.03	------	100.10	------	------
283707	C_2	43-60	[1] 39.24	.21	2.08	5.77	.047	18.93	7.99	1.36	.99	.05	.03	23.44	100.14	.031	9.50
			[2] 51.25	.27	2.72	7.54	.061	24.71	10.44	1.78	1.29	.07	.04	------	100.17	------	------

[1] Oven-dry soil (110° C.). [2] Mineral constituents only.

[5] The horizons of the Pedocal profile (vertical section) are not designated as A and B as in the Pedalfers. (Footnote 2, p. 11.) The lower layer in the Pedocal profile may be called the C horizon and the rest of the soil the Solum. In the description and discussion of the composition of the Pedocals in this ATLAS the solum layers are designated as such rather than as horizons for the reasons given in footnote 2, p. 11.

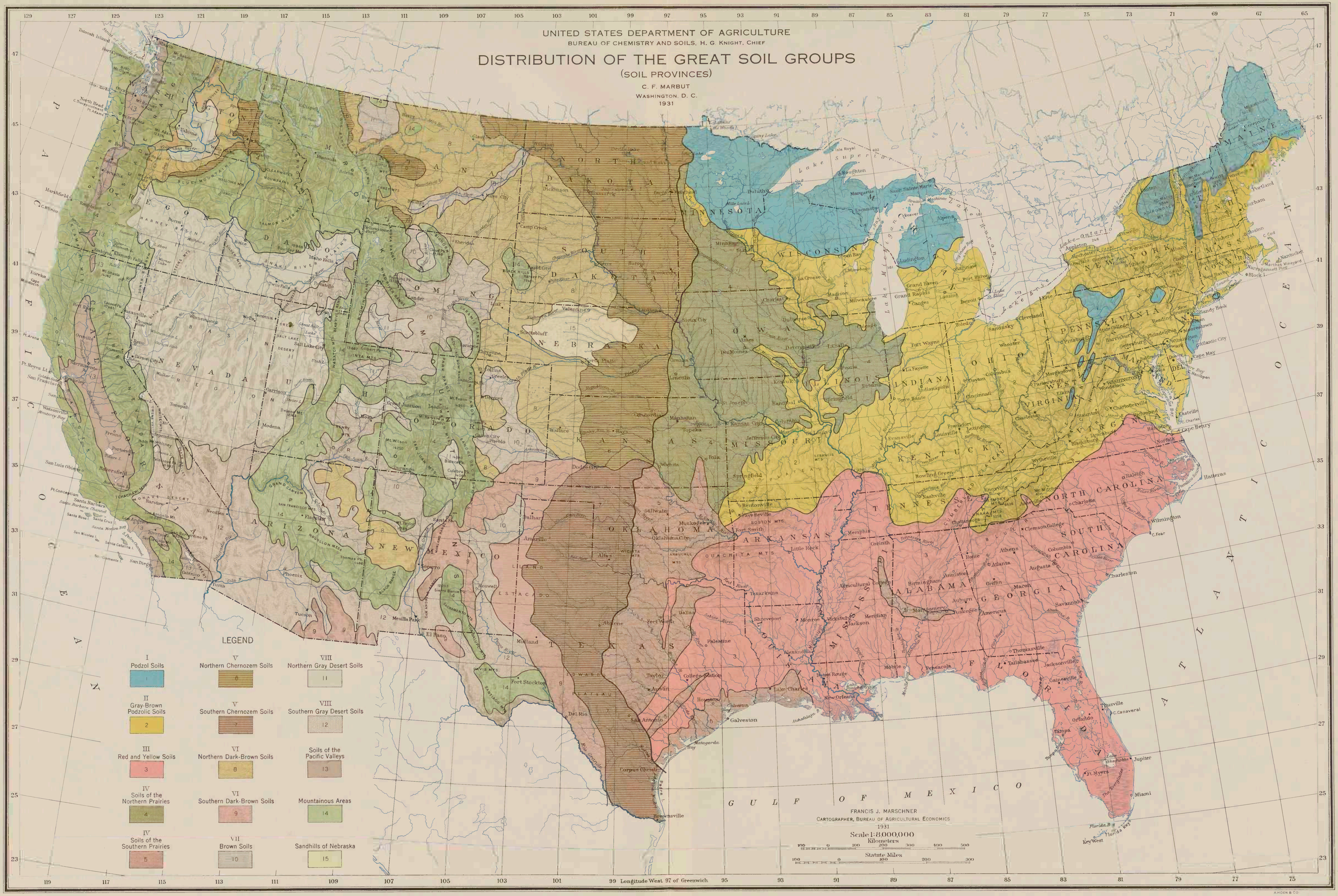

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF CHEMISTRY AND SOILS, H. G. KNIGHT, CHIEF
DISTRIBUTION OF THE GREAT SOIL GROUPS
(SOIL PROVINCES)
C. F. MARBUT
WASHINGTON, D. C.
1931
LEGEND
I Podzol Soils 1
II Gray-Brown Podzolic Soils 2
III Red and Yellow Soils 3
IV Soils of the Northern Prairies 4
IV Soils of the Southern Prairies 5
V Northern Chernozem Soils 6
V Southern Chernozem Soils 7
VI Northern Dark-Brown Soils 8
VI Southern Dark-Brown Soils 9
VII Brown Soils 10
VIII Northern Gray Desert Soils 11
VIII Southern Gray Desert Soils 12
Soils of the Pacific Valleys 13
Mountainous Areas 14
Sandhills of Nebraska 15
FRANCIS J. MARSCHNER
CARTOGRAPHER, BUREAU OF AGRICULTURAL ECONOMICS
1931
Scale 1:8,000,000
Kilometers
Statute Miles
Longitude West 97 of Greenwich
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN

Table 1.—*Chemical composition of a Pedalfer and of a Pedocal*—Continued

A PEDOCAL, KRYDOR, CANADA

Sample No.	Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Loss on ignition	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
33020	1	0-5	[1] 64.73	0.39	3.22	9.76	0.147	1.70	1.00	2.03	1.45	0.17	0.20	15.55	100.35	0.557	------
			[2] 76.65	.46	3.81	11.56	.174	2.01	1.18	2.40	1.71	.20	.23	------	100.53	------	------
33021	2	8-14	[1] 71.02	.49	3.49	11.27	.085	2.27	1.38	2.22	1.61	.13	.07	6.12	100.16	.152	1.01
			[2] 75.65	.52	3.72	12.04	.090	2.41	1.47	2.36	1.71	.13	.07	------	100.17	------	------
33022	3	15-24	[1] 59.26	.40	3.28	9.95	.063	8.40	3.13	1.85	1.34	.14	.07	12.11	99.99	.129	7.78
			[2] 67.42	.45	3.73	11.32	.071	9.55	3.56	2.10	1.52	.16	.08	------	99.96	------	------
33023	C	25-65	[1] 66.11	.63	6.18	14.17	.048	1.97	2.19	1.85	1.27	.08	.12	4.85	99.97	.033	.85
			[2] 69.48	.66	6.49	14.89	.050	2.07	2.30	1.94	1.33	.08	.12	------	99.41	------	------

[1] Oven-dry soil (110° C.). [2] Mineral constituents only.

In general the alkalies, alkaline earths, and P_2O_5 are low in the solum of the Pedalfer and high in that of the Pedocal. The loss on ignition is widely different in the two soils. In the solum throughout, the loss on ignition in the Pedalfer is low, in the Pedocal is high. The thin surface layer was not analyzed in the Pedalfer but was analyzed in the Pedocal. The loss on ignition in this thin layer in other samples of Pedalfers ranges around 8 per cent. Since the loss in the surface horizons of fully developed soils expresses mainly the percentage of organic matter present, the 8 per cent of loss on ignition in a thin surface layer of the Pedalfers shows that the two groups are more nearly alike in this layer than in the lower layers. The significant fact, however, is that the layer with high loss on ignition in the Pedalfers is thin, that in the Pedocals is thick.

The loss on ignition in both soils is high in the C horizon. This, as may be seen by consulting the column showing the percentage of CO_2 from carbonates and that showing the percentage of CaO, is due to the presence of calcium carbonate. The percentage of this constituent in the C horizon of the Pedalfer is greater than that in the C horizon of the Pedocal. This is a matter concerning the parent material and not the solum. Layer 3, however, in the Pedocal, which corresponds approximately to the B horizon in the Pedalfer, contains high ignition loss and high calcium carbonate, while none of the latter is present in the Pedalfer. This constitutes one of the two most striking differences between the two soils, the other being the differences in the amount of organic matter in the upper part of the solum. This layer in the Pedocal is the zone of carbonate accumulation, a zone due to the operation of soil-building forces and therefore a part of the solum. No such layer is present in the Pedalfers.

No attempt has been made to show the distribution within the United States of the groups in Category V. It is not yet known whether all Pedalferic soils may be included in the two groups of Tundra soils and Podzolic soils or whether there is a group of Lateritic or Laterite soils that are not at the same time Podzolic. When this has been determined it will then have to be determined, if this has not been done in the meantime, whether the line between the Podzolic and Lateritic groups, if there prove to be such a group, lies across any part of the United States. In like manner the boundary line between Pedocals of the Temperate Zone and of the Tropics may or may not cross the United States.

The distribution of the groups in Category IV is shown on the map of the great soil groups. (Pl. 2.) The major soil boundary, separating the Pedalfers from the Pedocals is shown by a heavy black line, being shown in greater detail than on figure 1. Its location in detail has been determined on this map by the mapping of the soil series on the soil map of the United States, Plate 5, sections 1 to 12. The map is self-explanatory for the most part. It will be noted, however, that the Prairie soils and the soils of each of the Pedocalic groups, except those of the Brown soils, have been divided into a northern and a southern subgroup. This has been done because the soil series, as shown on the large 12-sheet soil map, are different in the two parts of each group belt.

This may be considered a true soil province map of the United States. The soil provinces shown are the large provinces only. In the mountains of the West a great number of small areas, each of which is occupied by soils belonging to some of the great soil groups, is present, and each may legitimately be called part of a soil province. These areas can not be shown on Plate 2 because of their small size and the small scale of the map, but many of them are shown in at least their approximate location on the large map sheets. (Pl. 5, secs. 1 to 12.) They consist of small areas of some of the provinces shown in larger areas. None of them, so far as is now known, constitutes a new soil province. In the eastern part of the United States small outlying areas of some of the provinces are large enough to be shown. The most important of these are some outlying areas of Podzol soils or of the Podzol province, one large and three small ones in Pennsylvania and a large one in New Jersey. It is probable also that most of Cape Cod should be included in the Podzol province, but this has not yet been definitely determined.

The distribution of the great soil groups in the Pacific coast region has not been attempted.

The large soil map (pl. 5, secs. 1 to 12) of the United States shows the distribution of soil series (Category II) or of combinations of series so far as the accumulated knowledge will allow. It is based on all the data accumulated in the work of the Soil Survey since its beginning in 1899. In by far the greater number of cases the individuals or units on this map consist of combinations of a number of related series. The name given in the legend to the mapping unit is the series name for the dominant series within the area covered on the map by the unit.

Since the greater part of the text of this Atlas consists of a description of these series, their distribution, and composition, the map needs no further description here. The data-reliability-chart (inset on pl. 5, sec. 9) will show the source and character of the data used.

Since the scale of the map is not large enough to show the distribution, except in a very few cases, of individual soil series, even where that has been well worked out in the detailed work of the Soil Survey, it is evident that the scale is not large enough to make it possible to show the distribution of the soil types. The distribution of the units in Category I, therefore, is not shown.

DISTRIBUTION OF PARENT MATERIALS ACCORDING TO CHARACTER AND ACCUMULATION

Plate 4 shows the distribution of areas in which given kinds of parent materials or parent rock predominate. They have been differentiated on the basis both of the general mineralogical character of the material and of the processes by which it was accumulated. The parent geological material from which soils have developed constitutes the connecting link between those things which are the objects of investigation in geology, as usually understood, and those treated of in that branch of geology or at least a closely associated subject known, since it attained the status of a science, as pedology or soil science.

This chart is introduced as one of the ways of expressing the fundamental point of view regarding the relation of the sciences of geology and pedology maintained not only in this paper but throughout the work of the Soil Survey. The underlying point in this attitude is that the processes of accumulating rock débris, either by disintegration and decomposition of rocks or by the shifting and redeposition of this material in water, air, or ice, are geological processes and are fundamentally different from soil-developing processes.

That the two processes work side by side and contemporaneously no one doubts, and the geological processes, especially of rock decomposition, are deeply involved in soil building, but that fact does not make it any less obligatory for the investigator to think clearly regarding them.

The map with the legend is self-explanatory. It is evident that the scale allows only the broadest and simplest differentiations. The compilation of the soil map, Plate 5, sections 1 to 12, is almost entirely the work of F. J. Marschner.

DISTRIBUTION OF SOILS WITHOUT NORMAL PROFILES

Plate 6 shows in a general way the distribution in the United States of soils developed or developing under the influence of one or more of a small number of conditions resulting in a soil profile differing in some important respect, or respects, from the normal or usual mature profile of the region. In other cases the absence of a normal profile is merely the absence or only the incipient development of any profile at all. The most important conditions causing the development of an unusual profile or no fully developed profile are as follows: (1) Occurrence on slopes where erosion, creeps, and slides do not allow the material to lie in place long enough for the development of the regional profile, (2) high ground water, standing through a large part of the year at the surface or less than 4 feet below it, and (3) the presence in the parent material of a high percentage of certain salts, such as sodium carbonate, or of calcareous marls.

Large areas of soils with imperfectly developed profiles are shown on the map. These include soils imperfectly developed because of the recent accumulation of the material and those developing on slopes where the material is not allowed to lie in place long enough for the development of a profile. The latter occur mainly in the mountainous regions. One important area covers the sand-hill region of Nebraska and another the Edwards plateau of Texas, which is underlain by limestones. Only the larger areas of both kinds are shown. Numerous large areas that could be placed in the first subgroup of imperfectly developed soils have been included in the ground-water group. Most of the soils shown on the map as imperfectly developed are well drained.

Soils in which the unusual character of the profile is due to the presence of an unusually heavy tough intractable subsoil, called a claypan, occur mainly in the Mississippi Valley region. Their characteristics are described in the body of the report, but the cause of their development is not yet well understood.

Soils with indurated subsoils occur in the eastern part of the United States, around the lower Mississippi River, and in California. They do not include soils in which the zone or horizon of calcium-carbonate accumulation is indurated. The latter will be described in the body of this paper. Rendzinas or dark-colored soils developing from calcareous marls occur in two parts of the United States—in central Alabama and northeastern Mississippi, and in the eastern part of Texas.

Poorly drained soils occur mainly along the Atlantic coast and in the Great Lakes region. Most of these soils have imperfectly developed profiles because of their subjection to ground water.

THE COLOR-PROFILE CHART

The color-profile chart (pl. 3) shows the results of an attempt to reproduce the actual colors of soils in nature, but in approximately an air-dry condition. The colors shown are essentially those of the soil where it has been exposed in a bank long enough to have become dry on the face of the exposure. The charts were painted from large block samples of complete undisturbed sections or profiles.

The name of the soil type as well as the category to which it belongs are shown on the chart. The color profile is that typical of the series represented. The small sketch map (fig. 3) shows the positions of the localities where the samples were collected.

APPROXIMATE CHEMICAL AND MECHANICAL COMPOSITION CHARTS

The charts (pl. 7) showing approximate chemical and mechanical composition, represent the composition of a number of profiles of samples selected from localities where the soils were typical. The composition is representative, in its general features, of the type wherever it occurs and in a general way of the Category group to which it belongs. The explanation of the charts including their construction, is printed on the plate. The outline map (fig. 4) shows the localities where the samples were collected.

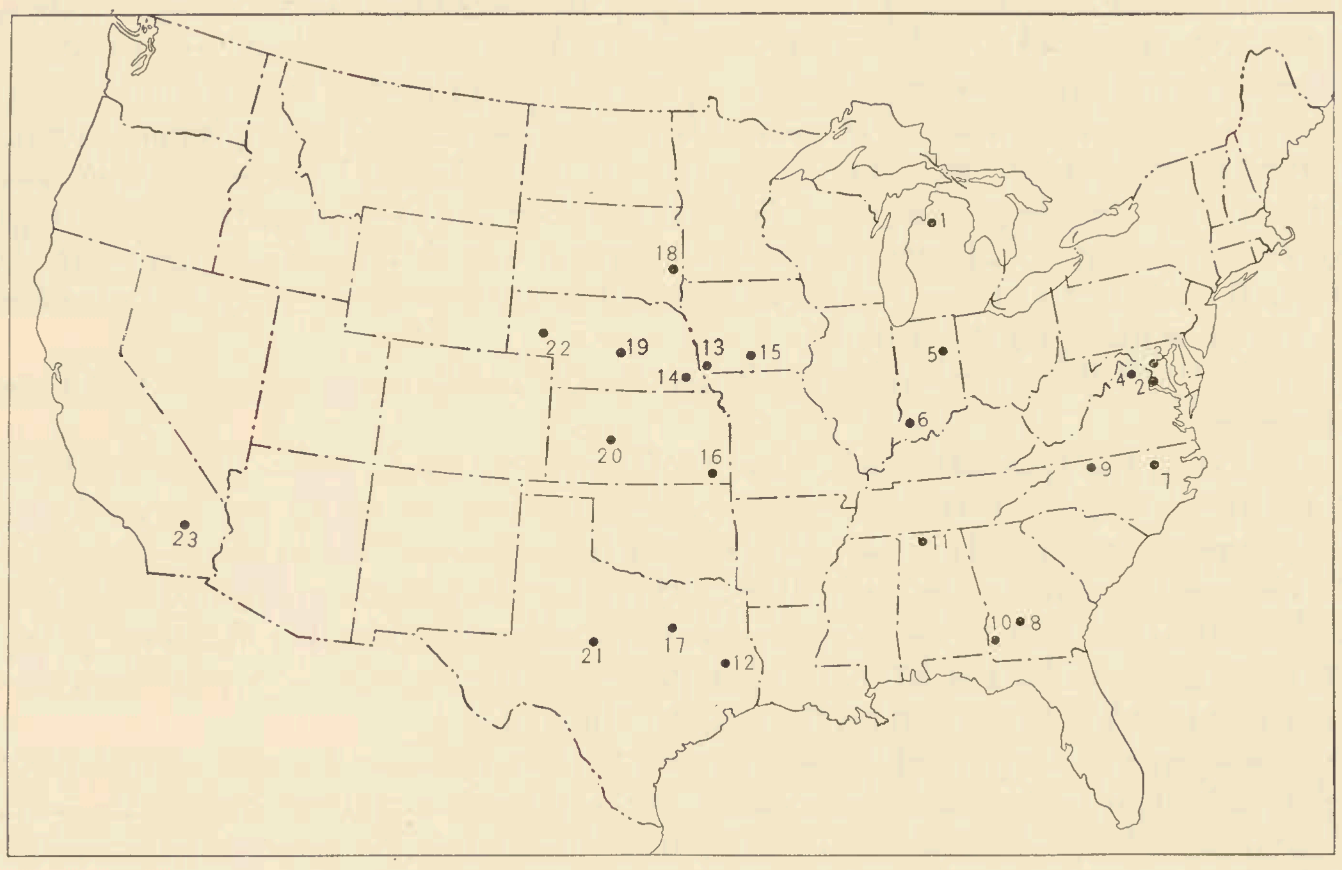


FIGURE 3.—Locations of soil samples used in preparation of color-profile charts.

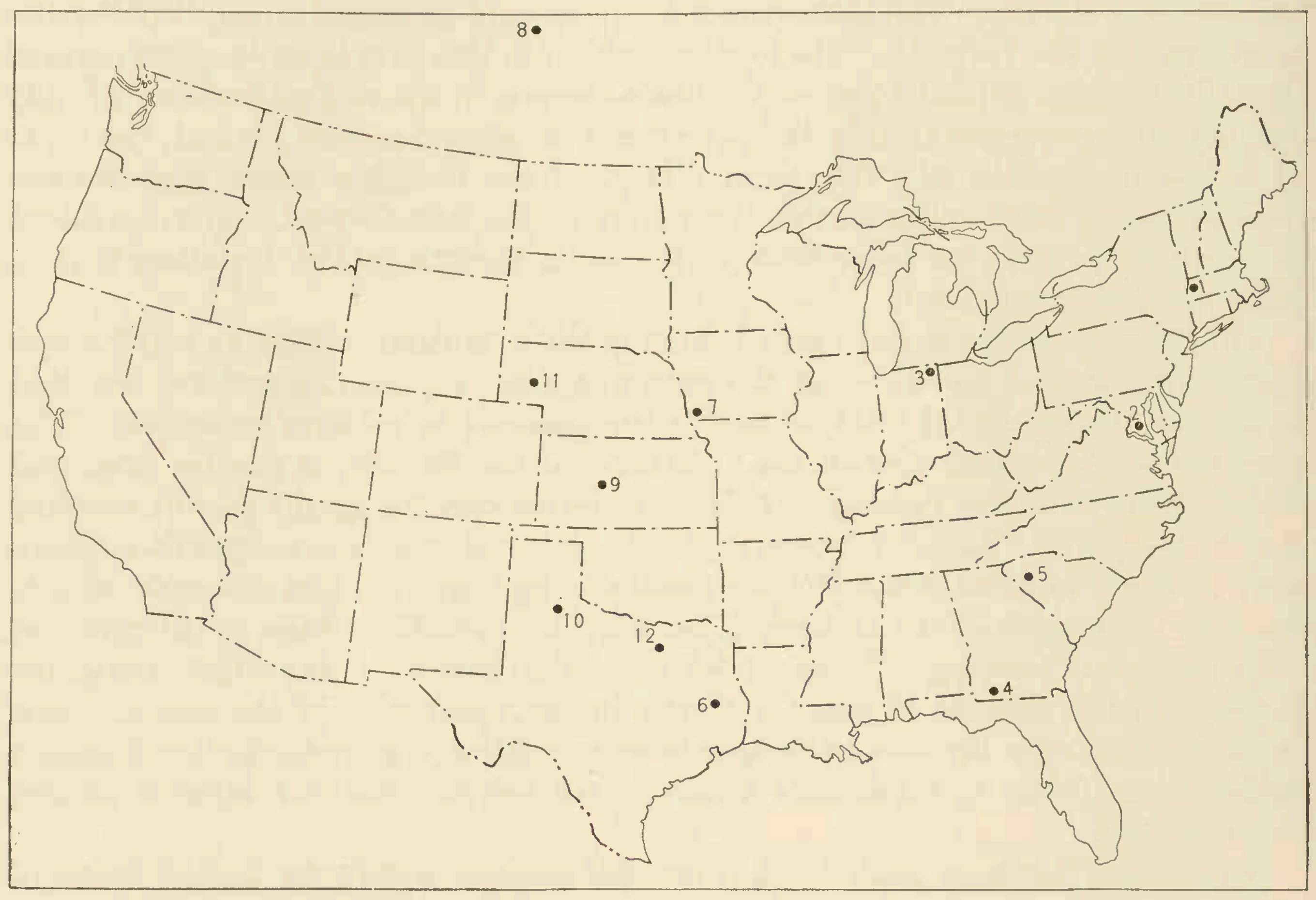


FIGURE 4.—Locations of soil samples used in preparation of chemical and mechanical profile charts.

HISTORY OF SOIL UNIT DEFINITION AND SOIL CLASSIFICATION IN THE UNITED STATES

When the work of differentiation of natural soils was begun in the United States, there was no established criterion to serve as a basis for doing it. All that had been done was to define in a very crude way certain units which were recognized, not as individual units but really as groups, and their definition was not based on their individual characteristics but on the basis of an assumed relation to other bodies. Broad soil units, recognized as groups subject to further separation into smaller units had been established in eastern Europe many years before the beginning of the twentieth century, but western Europe and eastern North America had at that time no knowledge of the results. This work in the United States, therefore, necessarily started from the bottom, except so far as our knowledge of the geologic formations of the country supplied a temporary basis.

Prior to the beginning of the twentieth century and subsequent to the middle of the nineteenth century, the science of geology attained an advanced stage of development. Since the materials of soils lie on the surface of the earth and constitute part of its crust, and since they have been derived from geologic formations, it was but natural and seemingly logical and reasonable to conclude that the characteristics of soils were determined by the characteristics of the rocks from which the soil material originated. Up to that time, no suggestion that the characteristics of soils were due to other agencies had received recognition in the United States. Such studies as had been made on the soil covered chemical studies of soil materials mainly, with little or no reference to the character of the soil, as it occurs in nature, from which that material came.

The study of the genesis, morphology, and evolution of soils, made necessary over a wide area by the work of the Soil Survey, has shown that soils are to a much greater extent the product of those factors which influence and in a measure control the development of organic life, the physical environment taken as a whole, than of the single factor of the character of rock material from which they have developed. It has also been determined that the characteristics of the soil at any given time and in any given spot consist of two kinds—those that may be defined as inherited and those that have been acquired. The quantitative relationship of the two differs from time to time. The inherited characteristics are those derived from the parent material or the geologic formation from which the material came, and they are dominant in the early stages of soil development. As the soil becomes older these characteristics become less and less dominant through the development of acquired characteristics impressed on the soil by the dynamic soil-building factors. By the time a stage of development that may be defined as maturity has been attained, these acquired characteristics become entirely dominant. This conception is, for the United States, an entirely new one and has been developed, so far as the details and their application to particular soils are concerned, through soil investigation within the United States.

When soil investigation in the field, designated in this country usually by the expression, "soil survey investigations," was begun in the United States, the soil characteristic considered most important was the texture of the surface layer, and, in the earliest work, differentiations were made mainly on this basis. On the basis of studies made while connected with the Maryland Agricultural Experiment Station, Prof. Milton Whitney came to the conclusion that the adaptability of the soil for a given crop, and the success with which a crop could be grown on any given soil, was dependent primarily, if not exclusively, on its texture. Thus the use of the texture of the surface soil as a basis for defining soil units automatically gave such units agricultural significance. The soil was thought of as a crop-producing body rather than as a natural body worthy of investigation as a contribution to human knowledge, and its investigation was justified on the ground that the information furnished was valuable in the promotion of crop production.

That the dominant reason for doing the work was practical rather than scientific is further shown by the limitation (during the first two decades) of the depth of soil examination in the field to about 3 feet. This limitation was arbitrarily based on the idea that the average farm crop extended its roots into the soil to about that depth.

The first work was done in the summer of 1899. This work, and that of the following year or two, was entirely local in character. A number of soil units were identified and separated, but they were differentiated on the basis of texture mainly and with little reference to their interrelationships. Differentiation of soils on so simple a basis made any relationships among the several units equally simple and limited. While this simple definition prevailed in the central office in Washington, the men in the field in actual contact with soils soon discovered that characteristics other than the texture of the surface layer were important soil features.

The number of texture units in soils, whose use is practical or convenient, is small, 15 in all, and work in the field soon revealed the existence of many other soil characteristics seemingly as important as the texture of the surface horizon. Before much knowledge of these characteristics had accumulated, except for restricted areas mainly in the eastern part of the United States, the concept of a group of soils arose, which would include a wide range of textures, possibly all known textures, but whose characteristics other than texture of the surface horizon were uniform. Such a group was designated as a soil series, and seems to have been suggested by the current geological explanation of the range of textures in a delta or other unit of deposition in standing water. It is certain that the idea arose before the knowledge of soil characteristics had accumulated to a sufficient extent for the suggestion to have been based on them.

By the definition developed from this suggestion a soil series was made to include the soils deposited in the form of a delta in a body of standing water. Material carried into such a body of water at a given point by a stream, would be spread out, according to the point of view regarding sedimentation prevailing at the time, more or less fanlike, thickest and with the coarsest texture at the point of entry, becoming progressively finer in grain with distance from this point. Theoretically all possible sizes of mineral particles would be found within the deposit, the range including gravels along the shore near the point of entry of material, and progressively finer grained material ranging through coarse sands, sands, fine sands, silts, and clays as distance from the point of entry increased.

According to such a definition a series was supposed to include all possible textures, and the characteristics other than texture would without question be those determined by the geological character of the rock and the process of deposition. In such a case, a soil series constituted a geological unit, and the characteristics of the bodies included in it were entirely geological.

As the work of the Soil Survey extended, experience was gained with soils over a wide range of territory and developed under a wide range of conditions. These included soils developed not only from sedimentary deposits, laid down in deltalike form such as was supposed to have taken place in order to produce the conditions for the original series definition, but soils formed from material accumulated by rock decomposition in place, not merely sedimentary rocks but igneous rocks also. Gradually, as a result of this accumulated experience, the definition of the soil series was modified and by almost imperceptible stages became more and more pedologic and less and less geologic. It finally became based on soil characteristics entirely, not neces-

COLOR PROFILES OF REPRESENTATIVE SOILS OF THE GREAT SOIL GROUPS

Color of soil is shown to a depth of 5 feet, except Cecil fine sandy loam which is shown to 10 feet

GREAT SOIL GROUPS AND THE REPRESENTATIVE SOILS SELECTED FROM EACH GROUP

PODZOL SOILS
Kalkaska loamy sand

GRAY-BROWN PODZOLIC SOILS
Sassafras sandy loam
Collington fine sandy loam
Chester loam
Miami silt loam
Gibson silt loam

RED AND YELLOW SOILS
Norfolk sandy loam
Tifton sandy loam
Cecil fine sandy loam
Orangeburg sandy loam
Decatur clay loam
Nacogdoches clay loam

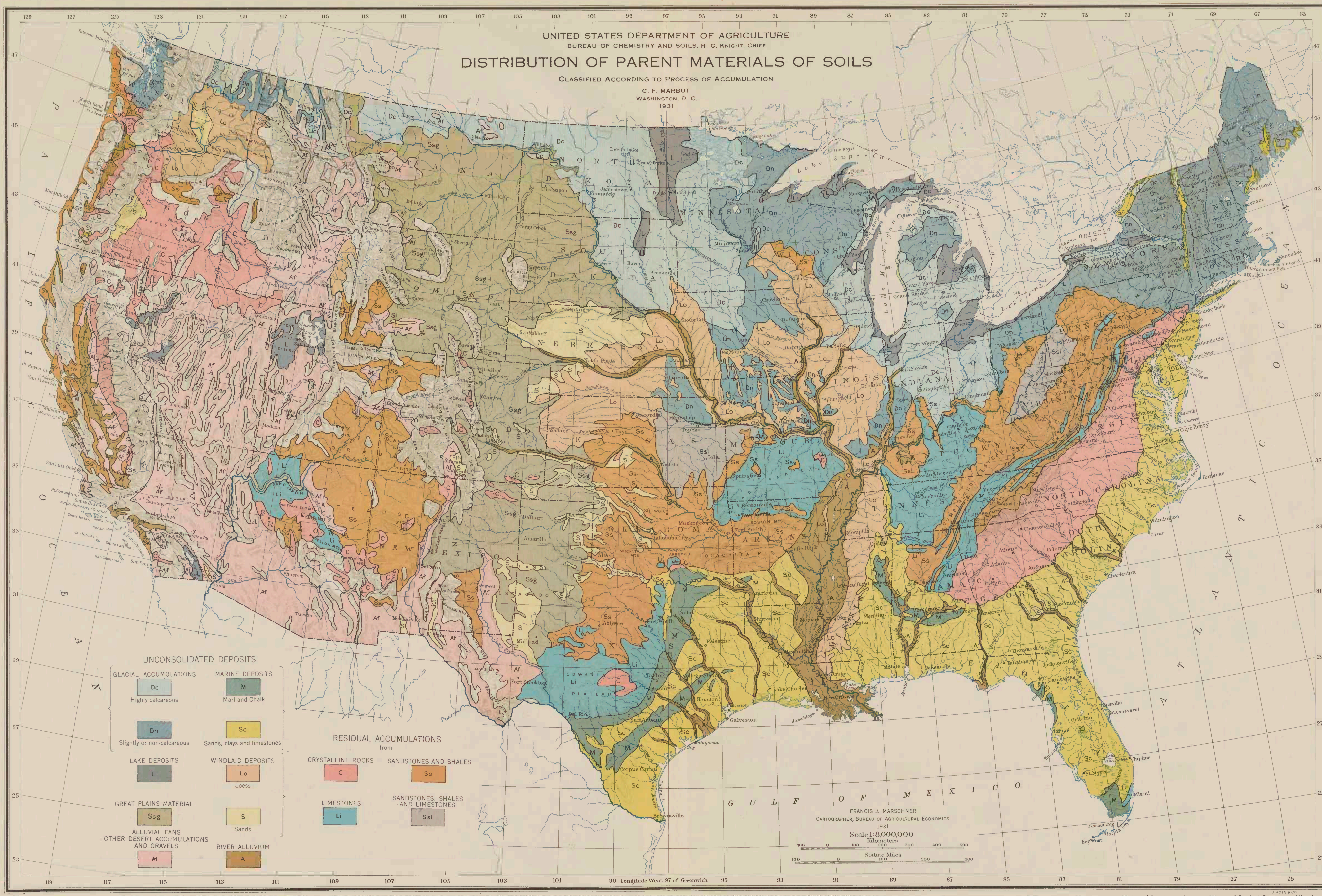
PRAIRIE SOILS
Marshall silt loam
Carrington silt loam
Grundy silt loam
Cherokee silt loam
Houston black clay

CHERNOZEM SOILS
Barnes loam
Holdredge silt loam
Greensburg clay loam
Abilene fine sandy loam

DARK-BROWN SOILS
Rosebud silt loam

DESERT SOILS
Mohave fine sandy loam

Lith. A. Hoen & Co., Inc.



This map shows the approximate distribution of the different kinds of unconsolidated materials from which the soils of the United States were developed. No attempt has been made to make it accurate in detail. In considerable areas there may be some legitimate difference of opinion as to the source and character of the materials, such for example as on the plains of Southern Idaho and parts of Central Oregon and Washington. In Central Texas the western part of the area of residual accumulations from sandstones and shales contain areas of Great Plains materials and sands. The distribution of loess has been extended over areas about which there is no universal agreement. Notwithstanding these and many other areas of detail about which there is no universal agreement, the map presents a mass of useful information. The "Residual Accumulations" constitute the parent material of the soil in the strict sense of the term as now understood by pedologists; but all those materials designated as unconsolidated deposits are more strictly defined as rock from which soil materials develop through decomposition.

sarily the characteristics of a mature soil and therefore pedological entirely, but, in the case of young soils, where the soil itself is, to a considerable extent, a geological body, some geological characteristics were retained. The soil series became, therefore, a group of soil bodies essentially alike in all soil characteristics except the single characteristic of the texture of the surface horizon, which, in the original definition, referred to the plowed zone.

Apparently there was no intention, at the time, of constructing a classification similar to that of plants and animals in which the soil series would correspond to the genus and the texture to the species. Since that time it has developed into such a similarity to the extent that each soil unit, like each plant or animal, is designated by two terms, one designating a group of characteristics, other than texture of the surface soil, common to all the members, the other designating the texture of the surface layer. A plant in a similar way, is designated by a generic term connoting all its characteristics except one which is called its specific characteristic.

The work during the first decade or more after inauguration of the Soil Survey gradually and, it may be said, inevitably accumulated knowledge of soil characteristics, yet because of the predominance of the geological rather than the pedological point of view attention was directed, even by field men, to the geology of the soil material rather than to the soil itself. The recognition of the soil as a body with entirely different chemical, physical, mechanical, biological, and morphological characteristics from the parent material beneath it did not become well established in the Bureau of Soils until the second decade of soil-survey work was well begun.

The breaking up of a soil series into its various texture members has always been done for the purpose of giving the soil type a practical value. As the work has progressed, however, during past years, the expression "texture of the surface soil," originally applying to the plowed layer, has gradually shifted its application to the "texture of the A horizon." [6]

The soil at a given spot with a given A horizon texture and with other characteristics designated as series characteristics constitutes a soil type.

All the soil types within a given area of country contain all the soil characteristics found within the soils of that area, and the differentiation of the soils of a region into soil types, as shown on the detailed soil maps and described in the reports of the United States Soil Survey, cover all the characteristics of all the soils in that region possible of recognition by the stage of development of the science at the time the studies were carried on.

As knowledge of soil characteristics has increased with the extension of field studies into all parts of the country, another important change in the soil series concept has taken place. Originally every series when complete contained theoretically as many members, texture units, as the whole number of textures that had been defined, 15 in number, not including the gravelly and stony members. As the definition of the series became pedological and was made to cover all soils whose soil characteristics are alike, except the texture of the A horizon, it was found by actual experience that each series included only a few texture units. Parent materials of coarse grain rarely and probably never develop into soils having the same series characteristics as those of fine grain.

COMBINING SERIES GROUPS INTO BROADER GROUPS

Soon after the series and type definitions had been rather well established it became desirable to group soil series into larger groups, constituting thereby a classification scheme of more than two categories. An attempt was made to establish it on a basis of distribution of soil series rather than more accurately on the character and relationship of the series in the various groups. Such a category in the scheme of classification was called a soil province and was more or less unconsciously recognized as a grouping comparable to series grouping. When it is realized, however, that the series and type groupings finally developed into groupings based on characteristics only, we realize that a geographic basis for the third category rendered the scheme inharmonious. The soil province as previously defined (*13*) is not a soil grouping but is a subdivision of a region on the basis of soil characteristics. Soil grouping must be done on the basis of soil characteristics only. If, however, a grouping of soil series into related groups brings together soils which occupy a given region, so that the grouping according to characteristics when interpreted in a geographic sense is equivalent to the establishment of a soil province, the significance of the grouping is thus enhanced, but this does not convert a soil province as a geographic unit into a part of a logical scheme of soil classification.

Mature soils are the product of their environment. In a region like the United States, where environments, including not only the factors of the dynamic environment but also the conditions on which these factors must operate to produce soils, are uniform over large areas, the soils produced under the influence of each of these environments, constituting members of a given category of soils when placed on a map, will each occupy the whole of such an area. Such a map may legitimately be called a soil-province map.

The provinces on the first soil-province map, published by the Bureau of Soils in Bulletin 55 (1909), were not soil provinces, since the soils of none of them belong in the same pedological group. In some of them, parts of several pedological groups were included, others included much less than the soils of a single group. This resulted necessarily because the basis of subdivision of the country into provinces was, in part geology, in part physiography, and in part general-areal geography. In no part of the map was a soil basis used.

After the construction of this province map it was used as part of a scheme of soil classification. If soils in two localities on opposite sides of a province boundary were found to have identical characteristics they were nevertheless placed in different soil series because of such occurrence. There were a few isolated cases where this was not done.

About 1915 it became evident to the workers in the Soil Survey, that this basis of classification was not satisfactory, since by that time it had been determined that the differentiation was not based on soil characteristics. About this time the results of Russian work, done in the last quarter of the nineteenth century and the first decade of the twentieth, became known through German translations. At first it was thought that the Russian system could be adapted to the United States, and an attempt was made to do so. In a short time, however, it became evident that, although the results fitted much more closely to actual soil characteristics than did the old geographic and physiographic map of the Bureau of Soils, the adjustment could not be made exactly because of a much wider range of environmental differences in the United States than in Russia. It was evident that in its general features the Russian classification scheme was fundamentally sound. By the time, however, that knowledge of the features of the scheme had become familiar to us, a very great deal of information regarding soil characteristics of the soils of the United States had been accumulated, and since the Russian classification, or at least its explanation, was based on features of the climate, it was found to be only partly applicable. The workers in the United States became convinced that a fundamental scientific classification of soils should be based on the characteristics of the soils alone. For several years, therefore, persistent attempt was made to work out a scheme which would be based on soil rather than geologic characteristics, climatic characteristics, biologic characteristics, or the characteristics of any group of bodies other than soils themselves. The first attempt to group the soils of the United States into groups on the basis of fundamental soil features alone, as these are expressed in the soil profile, was made in 1922 (*11*).

So far as is now known, this was the first attempt to group the soils of a large continental area on the basis of soil-profile characteristics alone without reference to geographic distribution or climatic, geologic, botanic, or other features than those of the soils. The groups established were soil groups, and in their construction soil characteristics alone were taken into consideration. Where the distribution of these groups is laid down on a map of the United States, however, it is found that each group occupies one or more large continuous areas within the smooth or relatively smooth parts of the country. In the mountainous parts of the country, such as the Rocky Mountain region or the Pacific coast region, the distribution is in small areas. On the basis of our experience up to the present time, we seem to be justified in stating that all soils in the United States may be included in these groups.[7 8]

These groups correspond in part to the soil-type groups established by Russian pedologists in the last quarter of the ninteenth century. The Russian types include Podzols, Laterites, Chernozems, Chestnut-Colored soils, Brown grassland soils, and Gray desert soils. True Laterites do not occur within the United States.

Because of the greater number of what seem to be distinct kinds of environment in this country than in Europe, the American workers have created a greater number of groups or types, in the Russian sense, than have the Russians. All the Russian groups are included and may be definitely identified in this country. In the United States the following groups have been defined: Podzols, Gray-Brown Podzolic soils, Red soils, Yellow soils, Prairie soils, Chernozems, Dark-Brown soils, Brown soils, and Gray soils. The distribution of these groups (described on p. 13) is shown on the map. (Pl. 2.) This brings the development of the classification up to the present time.

THE PODZOLS

Podzols are dominant in the northern part of the Great Lakes region, east of the boundary between the Pedalferic and Pedocalic soils, and in sandy areas of New York, New England, New Jersey (fig. 5), and to a slight extent farther southward along the coast. Their general distribution is shown on the map. (Pl. 2.) The main areas may be defined as those of the Great Lakes region, those of New England and northern New York, and those of New Jersey. Small areas lie in the Allegheny Plateau where the elevation is sufficient for a climate like that of the northern lake region or northern New England. These soils occupy a region in which the rainfall is high and the temperature low, as compared with that of the rest of the United States, or areas where the soil material consists mainly of sand which is readily attacked by the forces of leaching. Because of the low temperature and high rainfall, the soils remain in a more moist condition throughout a greater part of the year than soils in any other part of the United States. Like all the groups of Pedalferic soils, except the Prairie soils, the Podzols have developed under forest cover, but for the most part under a cover containing a somewhat larger percentage of conifers and of plants which flourish on an acid soil than is the case with other members of the Pedalferic group. Although the Red and Yellow soils in the southeastern part of the United States, when the region was first visited by white man, were covered with a vegetation consisting mainly of conifers, they do not support an undergrowth of acid-loving vegetation similar to that on a large part of the area of the Podzols.

The dominant vegetation on the extremely developed Podzols of Europe, most of which are very sandy soils, consists of the common heath plant (*Calluna vulgaris*). That plant is not the characteristic Podzol plant in the United States or apparently anywhere in North America. The very sandy Podzols in the United States are cov-

[6] In soil profile description the several horizons or layers in the soil from the surface downward are designated by letters of the alphabet. Since the soil horizons are more clearly defined in the humid or podzolic soils than in any of the other groups it is simpler to describe the horizons in these only. The A horizon lies at the surface and is a horizon of impoverishment. It has lost part of its iron, alumina, and other constituents except silica, and as a result of the removal of other constituents the silica left behind constitutes a larger proportion of the horizon than before. It is also coarser in texture than it was originally before soil development began. It ranges in thickness from a mere film to several feet but is usually a little less than a foot thick. The B horizon underlies the A and has been enriched by part of the material removed from the A horizon, especially the iron, alumina, and the fine-grained material. In some cases it contains more alkalies and alkaline earths than originally. It is a zone of enrichment. It ranges in thickness from a few inches to 3 feet. The C horizon underlies the B. It often consists of two parts. The upper part has been changed by weathering, including leaching of carbonates and other readily removable constituents, but very little or no other change has taken place. The lower part is one that has been less changed by weathering, consisting of the country rock, disintegrated and decomposed but not leached of its carbonates. It may consist also of consolidated or unconsolidated rock.

[7] These are the groups described on p. 13, under Category IV, and need no description here.

[8] It will be borne in mind that the changes in the province grouping described in this paper and even the change from no province grouping to the grouping on the 1909 province map, have not made necessary extensive changes in the detailed mapping previously done. It has involved, to be sure, the reconnaissance mapping which was carried on on the Great Plains between 1905 and 1915, but since only a relatively small amount of this work was done compared with the total area of the United States, the changes that will be made, when the same area is mapped from a modern point of view, will not be highly significant. The change in province definition, and therefore province mapping, has concerned higher categories in the scheme of classification than the categories involved in the detailed mapping. As explained before, the detailed mapping at the beginning was based primarily on the texture of the surface horizon, and the texture unit of a soil series is still based on the same feature. In constructing the first province map the provinces were mainly geological. The original theoretical definition of soil series was geological also but it was largely an office definition, and while it had some weight in the first few years of soil mapping, within a few years after the work was inaugurated the weight of facts obtained by men in the field demanded a soil characteristic basis for series definition. In many cases the names and definitions of soil series have been changed but in most cases this has been necessary because of the increase in our knowledge of many series, originally defined on the basis of limited knowledge, rather than because of change in point of view as to soil evolution or relationships. Soil type definition is now and has been for more than 20 years, based primarily on soil characteristics, and all the soil types in the United States will, when they have been identified and mapped, embrace all the soil characteristics in the United States, or all that have been discovered up to the time that the mapping was done in each particular area.

ered with pine or hardwoods, with an undercover mainly of blueberry bushes (Vaccinium). The large area of sandy heaths, or heide, which cover large areas in northern Germany and Denmark, have no exact duplicate in this country or in North America.

In general the Podzol profile is as follows:

1. Covering the surface is a layer of accumulated organic matter consisting of leaves of forest trees and other forest débris ranging in thickness from an inch or two to a foot, or, in extreme cases, even more.[9] This material is brown, only partly decayed, acid in reaction, and wholly without structure. In an extremely developed Podzol profile it overlies the mineral soil abruptly, there being a sharp boundary between the layer of organic material, or raw humus as it is called, and the mineral soil. In the United States, however, in most cases, the upper part of the mineral soil contains more or less partly decomposed organic matter. In an extreme profile, the raw humus layer will continue as raw humus to the bottom of the layer, but in the United States there is generally a layer, immediately above the mineral soil, of somewhat better decomposed material.

2. The upper part of the mineral soil consists of a gray layer, the bleicherde. This may be gray or white from the top downward, or it may contain an admixture of organic matter in the upper part. The lower part is always gray and it ranges in thickness from a mere film to a foot or more. It is structureless, but may have a laminated arrangement, and in chemical composition has a high content of silica, and a content of iron, alumina, alkalies, and alkaline earths lower than that in the horizon below. The upper part, with an admixture of organic matter, where such is present, is usually designated as the A_1 horizon and the lower part the A_2 horizon, and the raw humus layer is usually designated as the A_0 horizon.

The bleicherde is underlain by a brown, dark-brown, or coffee-brown horizon which may or may not be indurated. The induration usually varies with the texture, being highest in sandy material and less in clay. The brown, dark-brown, or coffee color is more intense at the top of the horizon than below, the thickness of the deeply colored layer varying from a mere film to several inches. The material gradually becomes lighter in color with depth, grading through rich brown and yellowish brown, and finally passing into the underlying material, the parent geologic material, whatever that may be. This horizon, or layer, is designated as the B horizon and is a horizon of enrichment, the enrichment including organic matter, hydrated iron oxide, compounds of alumina, and occasionally some of the alkalies and alkaline earths. The enrichment in any given case does not necessarily consist of all these constituents, but may consist of hydrated iron oxide in one case, compounds of alumina in another, and organic matter in another, though usually where the enrichment involves a great deal of organic matter, it also involves a great deal of alumina. Where the enrichment consists mainly of iron oxide, that in alumina may or may not be important. The material is usually structureless and has an acid reaction.

FIGURE 5.—Natural vegetation on Lakewood sand, a Podzol, Monmouth County, N. J.

SOILS OF THE PODZOL REGION

Only a small amount of detailed soil survey work has been done in the Podzol region as a whole. This is especially true of Maine, New Hampshire, Vermont, and New York. That part of Michigan lying within the region (pl. 2) is rather well known, but little is known of the soils of large parts of northern Wisconsin and northern Minnesota.

On the soil map, plate 5, sections 1 to 12, the soils of the whole belt, including the Podzol areas in the Allegheny Plateau, have been differentiated into six units, each unit consisting of several soils. In areas like that of the northern part of the northern peninsula of Michigan, where detailed studies have been extended over most of the land and the soils differentiated in detail, several closely related soils were grouped into one unit and the name of the dominant soil in the group was given to this unit which was shown under that name on the map. For example, on the soil map (pl. 5, sec. 2) the Ontonagon soils are shown as occupying a considerable area. Actually the true Ontonagon soils occupy only a part of this area, but soils closely related to the Ontonagon in character occupy the rest. The Ontonagon soils as shown on the map include, therefore, some five or more different soils, all of which are similar in their general features.

In regions like northern New England, where practically no detailed field studies have been made, large areas are shown as a single soil. Enough is known of the region to warrant the statement that it contains at least half a dozen important soils, but all of them have certain general characteristics similar to those of the Hermon soils which have actually been identified and their characteristics moderately well worked out in a small area in northwestern Massachusetts. On the basis of a small amount of very general knowledge of the soils of the region as a whole, supplemented by somewhat better knowledge of the character of the environment, the Hermon soils have been extended over northern New England, and in large areas in all the other States within the region. In most of the eastern part of the United States field research has been extended so widely that much more definite knowledge of the soils is available, and the map is more detailed and more reliable than that part of it covering New England.

The groups shown on the map (plate 5) as members of the Podzol group are six in number and are designated as Hermon, Caribou, Ontonagon, Dekalb, Beltrami, and Sand. In detailed mapping the sands within this region are differentiated into a number of soils, but sands have been designated as Sand throughout the map regardless of their character.

In many localities in southern New England, south of the region where the Podzol profile is developed in practically all the soils and well within the zone of dominant oak and chestnut forests, the sands, in many places, have a well-developed Podzol profile. At the present time such spots are covered with conifers, probably in most cases white pine, of second growth, since these sand areas, especially the sand plains, were put into cultivation at an early date. Large areas of sands occupy Cape Cod and large parts of Nantucket and Marthas Vineyard. Important areas lie south of Port Jefferson, Long Island, and in other areas on the island east of that town. Eastern New Jersey also is covered by an area of sand still larger than any of the individual areas already mentioned.

The soil profile throughout these areas is a typical Podzol profile in every respect except that of the cover of forest débris. The typical brown raw humus, described in textbooks as an essential or at least a characteristic feature of the profile, is not present, its place being taken by another form of layer. It is not yet known whether or not this form of raw humus is present in the United States where the Podzol profile has developed under deciduous forest cover.

The type of raw humus cover in these areas of Podzols, developed from sands, consists of a brown loose top layer of undecomposed leaves from the last leaf fall. This is underlain by a layer about an inch thick of slightly compacted flat-lying leaves, slightly decomposed but still retaining their brown color. Beneath this is a layer about 2 inches thick of dark-brown or very dark brown leaf fragments in which many of the leaf ribs are still distinguishable but the interrib membranous parts are much decayed. The whole layer is woven into a tough mat by a great many rootlets which penetrate it in all directions. Many white sheets and filaments of fungus mycelia are present.

This layer is rather abruptly underlain by the mineral soil (sand), but the upper inch or two is somewhat impregnated with organic matter. The rest of the profile is that of a typical Podzol. The B horizon usually assumes the form of ortsand rather than ortstein.

FIGURE 6.—Profile of Lakewood sand, a Podzol, Monmouth County, N. J.

Certain areas of sand occur in southern Delaware, southern Maryland east of the Chesapeake Bay, and southward along the coast at least into North Carolina. In these the Podzol profile is clearly defined, but less well developed than in New Jersey. (Fig. 6.)

The Hermon soils are the dominant Podzols of the region. They have developed under a cover of mixed forest in which conifers constitute an important element. Large areas were covered originally with deciduous trees, these usually occupying the areas of soils heavier than sands or very light sandy loams. Partly because of the rather heavy texture of the material, most of the areas covered with deciduous forests have a less well-developed Podzol profile than areas of lighter texture where conifers are more important.

The Hermon profile in northwestern Massachusetts consists of a raw humus layer about 4 inches thick, a bleicherde, or gray layer, constituting the upper part of the mineral soil and averaging about 2½ inches thick, and beneath this a rust-brown orterde,[10] or B horizon, ranging up to 12 or more inches in thickness. Beneath this, the lowest horizon of the true soil, lies the parent material consisting of glacial drift, made up of material from crystalline rocks, which differs in character rather widely from place to place.

Recent work shows that this profile is present in parts of Vermont, but no work has been done in New Hampshire and in most of Maine. The extent to which this profile, which is regarded as a well-developed Podzol profile, is developed in these States is unknown.

Enough data are at hand to show that the typical profile, as just given, is not fully developed throughout the region of occurrence as shown on the map. Recent work in Vermont shows that a very important part of the region has a profile in which the gray layer, lying normally beneath the raw humus, is not present. In such case the orterde lies at the top of the mineral soil, immediately beneath the raw humus, and it can not contain any accumulated iron oxide since the latter must come from an overlying layer of mineral soil.

The most important soils in northern New England, considered from the agricultural standpoint, consist of what are shown on the soil map (pl. 5, sec. 1) as Caribou.

[9] It is doubtful whether a layer of organic matter as thick as a foot overlies any of the Podzols in the United States since these soils occupy the southern part of the Podzol region on the North American Continent, and soils representing the extremes of podzolic development are not present in the United States or they occur in small areas only. They seem to be better developed north of the international boundary in Canada.

[10] The normal orterde is rust brown and contains a higher percentage of iron oxide than the gray layer and usually also of organic matter. Both the iron oxide and organic matter have been carried down in solution from the overlying horizons, the former from the gray layer and the latter from the raw humus. It is a horizon of enrichment, therefore, the enrichment consisting mainly of iron oxide, organic matter, and alumina, but it may include other constituents. The gray layer, on the other hand, is a layer of impoverishment, one from which material has been taken.

An important area lies in northeastern Maine and a large one also in northern Vermont. A considerable part of the area in Maine has been worked out in detail, and the general characteristics of the soils are well known. The northern Vermont area has not yet been worked out. Recent work has shown the existence, however, of a group of soils not identical in character with the Caribou soils of Maine but similar to them.

The Caribou soils in Maine have a clearly defined Podzol profile, developed under a forest cover consisting of mixed conifers and deciduous trees, in which deciduous trees have been important and possibly dominant, the two most important species being sugar maple (*Acer saccharum*) and yellow birch (*Betula lutea*). These soils have developed from glacial drift consisting of material derived mainly from fine-grained and somewhat calcareous crystalline schists. The soil material is relatively fine in grain, the texture of the surface soil being loam.

The soils in northern Vermont have also developed under a cover of mixed forest, with maple and birch constituting the dominant trees. They have developed from glacial drift derived from fine-grained crystalline schists which have some calcareous constituents in the form of lenses or in larger bodies. The soil material is somewhat heavier than that in the typical Caribou soils, and, partly because of this heavy texture, the Podzol profile is not well developed. The gray layer, or bleicherde, is absent over considerable areas, but the orterde is moderately well developed, beginning immediately at the top of the mineral soil. These soils are not members of the Caribou series and have not yet received a name, but as they are closely related to the Caribou they constitute part of a Caribou group. They occupy a region, both in Vermont and Maine, of rolling relief, decidedly less rough than the greater part of the area in which the Hermon soils of the New England region occur. They differ from the Hermon soils in their predominantly heavier texture, their higher lime content, in general their less leached condition, the less advanced stage of Podzol development, occurrence on smoother relief, and small content of stone.

The Dekalb soils are Podzols, developed from sandstone and shale material in small areas on the highest parts of the Allegheny Plateau in New York, Pennsylvania, Maryland, and West Virginia. As shown on the soil map (pl. 5, secs. 1 and 8), they have been developed from material accumulated in part by glacial deposition and in part by residual decay of the country rock in place. The character of the material is essentially identical in both cases, and because of the relatively small area covered the soils were not differentiated into two series. The soils have a definite Podzol profile, though the gray layer is usually not thick. On the whole, it is as well developed as in the Podzol region. The forest cover is mixed, but mainly deciduous, and the layer of raw humus, as everywhere in the United States, is thin, ranging up to 4 inches, is relatively fine in grain, relatively dark in color, but is structureless. Sphagnum moss is present in but few places.

In the southern peninsula of Michigan the soil material has been derived mainly from sedimentary rocks, and a large part of it within the Podzol region consists of sand. In addition to the sandy material and heavier ice-laid glacial drift distributed here and there, varying considerably in character, considerable areas of reddish heavy material are present, especially in belts lying along Lakes Michigan and Huron. This material is calcareous, contains a relatively high percentage of iron oxide, is relatively heavy, and is interpreted as a former lake deposit which was in some cases, if not in most, reworked by the ice and deposited as ice-laid material. This position of the material has not changed its character in any respect but has given the surface a different relief. In places where the reworking was very slight the relief is smooth, and the soil has been identified as Ontonagon. The Podzol profile is only slightly developed because of the heavy texture of the material as well as of the calcium carbonate content. It is apparent, however, that the carbonate content has been less effective in delaying podzolization than has the heavy texture, since it has been leached below the level of the soil profile. In most cases the bleicherde is only an inch or two thick and may consist of a mere film. The orterde can not usually be identified as such, and while there seems to be a slight accumulation of organic matter below the thin bleicherde, it has not been sufficient to cement the layer. In certain sandy areas, mapped as Ontonagon sandy loam, the bleicherde is thicker and organic material has been accumulated in the B horizon to a sufficient extent to cement it into an ortstein.

As is true of the Hermon soils, the Ontonagon soils as shown on the map, include a number of soils, all, however, related to the Ontonagon in character.

A large area of Sand occupies the central-northern part of the southern peninsula of Michigan, the whole area lying within the region where Podzol profile development is taking place. As is well known, Podzol profile development will take place in sand in a more southern latitude more readily than in material of heavy texture. This is well shown in New England where the Podzol profile is developed in southern New England on sandy areas but is not developed on the heavier textured soils. Such areas, however, are not shown on the map. That part of the map covering the central-northern part of the southern peninsula of Michigan shows the area merely as Sand, and this sand is not differentiated from sands in other parts of the United States. Because of the small scale of the map it was not advisable to attempt to differentiate sands into the different kinds in most regions. In detailed mapping this Sand area, a large part of which has been covered, has been differentiated into several soil series, but they can not be shown on the soil map. (Pl. 5, sec. 2.)

Associated with the Sand in both the southern and northern peninsulas of Michigan, the map shows a considerable total area of Hermon, a smaller area of Ontonagon, and a still smaller area of Summerville soils, consisting of a thin layer of soil material overlying rock. The Podzol profile has not been developed in the latter but is moderately developed in the other two.

In northern Wisconsin, the Ontonagon soils cover a large part of the region, the Hermon a larger part, while in the central part of that State, lying practically on the extreme southern boundary, if not actually stretching over the southern boundary of the Podzol region, is a large area covered by the Spencer soils. The Spencer soils have developed from light-colored glacial materials on smooth relief, so smooth that under natural conditions surface drainage was not perfect. They have a moderately well-developed Podzol profile, but because of the heaviness of the material the B horizon, or orterde, has not been well developed. They are in a similar stage of development as that of the Ontonagon soils.

In northern Minnesota two important soil series are shown on the map, the Beltrami (fig. 7) and the Hermon. The Hermon soil in this State is essentially identical with that in northern Wisconsin and Michigan and similar but not identical with the Hermon soils in New England. The Beltrami soils have been developed from highly calcareous glacial drift. The area shown as Beltrami soil on the map consists of Beltrami and a number of associated soils, such as the Taylor and Nebish soils. All of these, however, have been derived from calcareous glacial drift and have been differentiated one from the other partly on the basis of profile development, partly on the presence of lime in the parent material, and partly on the color of the soil. Fundamentally and in general characteristics they are similar. They are all Podzol soils developed from relatively fine grained material in which the Podzol profile is better developed than on similar material in any other part of the United States with the possible exception of the Caribou. The layer of raw humus overlying the surface is thin, as elsewhere in the United States.

So far as is now known, with the possible exception of certain areas in the higher mountain regions of northern Maine or the mountains of the West, there is no such accumulation of raw humus in the Podzol region of the United States as in northern Europe. The layer is rarely thicker than 3 inches. In the Beltrami soils the bleicherde or gray layer, is well developed, attaining a thickness of about 8 inches, the upper 2 or 3 inches being colored dark by the incorporation of organic matter. The B horizon is a moderately well developed dark-brown or brown orterde about 12 inches thick. This is underlain by the parent calcareous glacial material.

It is well known that Podzol soils occur in the high mountains of the Rocky Mountain region, at least from Colorado northward, but none of this region has been mapped. Such areas of Podzol soils are not shown on the map. It is apparent that in the northwestern part of the United States, except in the higher parts of the Cascade and Olympic Mountains, Podzol soils do not occur. Although the region contains the most luxuriant forest growth of any part of the United States, a considerable amount of forest débris has accumulated on the surface. This débris overlies a brown or grayish-brown soil which seemingly does not contain precipitated organic matter like the incipiently developed Podzols of New England. Chemical analyses have not yet determined whether this brown soil is entirely saturated with bases or not. In various parts of the southeastern United States, soils in flat areas where the water table stands near the surface have developed a podzollike profile. This profile is a ground-water profile and is not a normal Podzol profile.

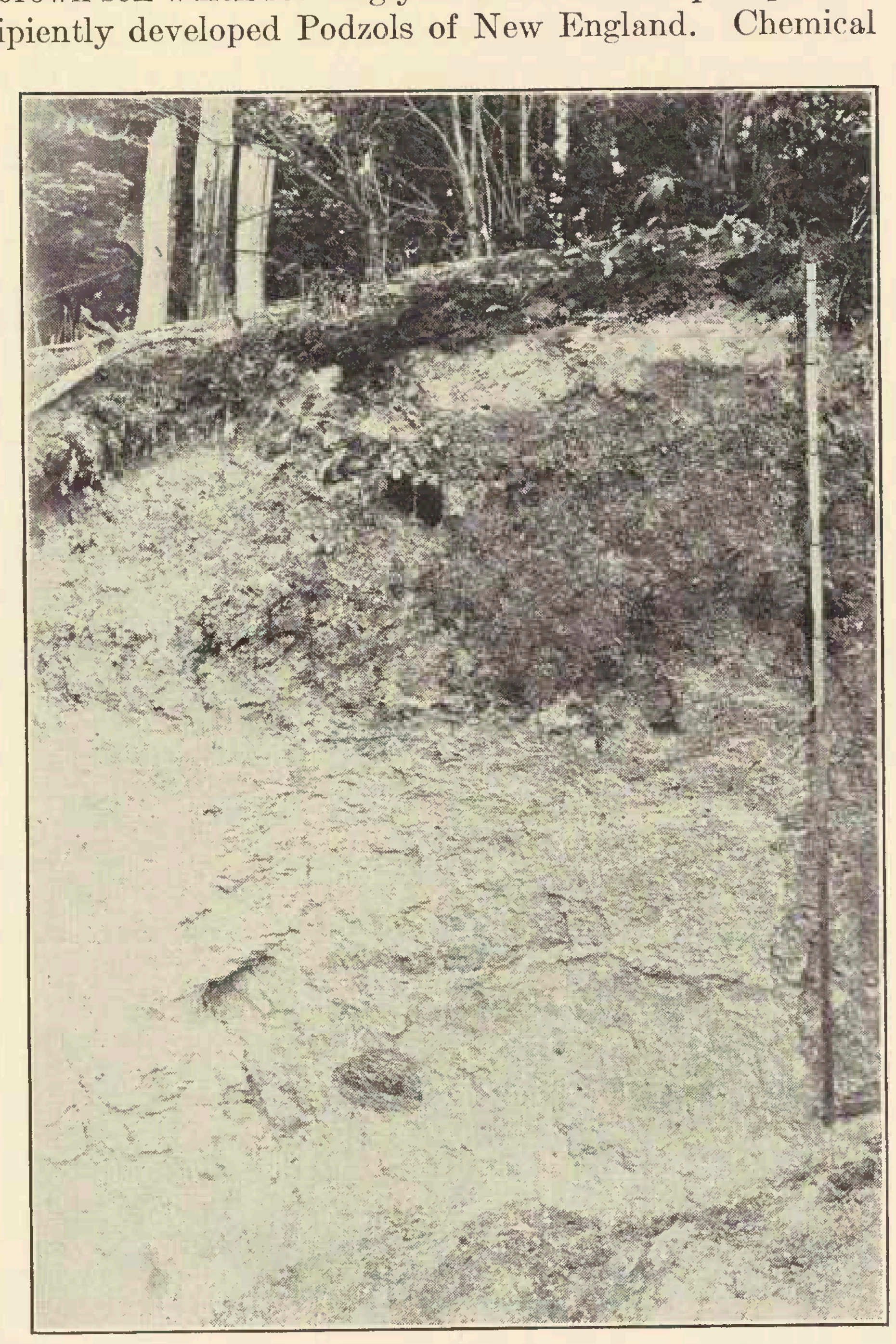


FIGURE 7.—Profile of Beltrami silt loam, a Podzol developed from calcareous parent material and covered by hardwood forest, in northern Minnesota.

COMPOSITION OF THE PODZOL SOILS

The chemical and mechanical composition of seven Podzol soils collected from widely distributed localities throughout the Podzol region are shown in Tables 1 to 14. They include soils from Becket fine sandy loam (Hermon), Caribou loam, Ontonagon silt loam, Hibbing loam (Hermon), Taylor clay loam, Beltrami silt loam, and Dekalb stony loam. In each case the Podzol profile is moderately well developed. The Becket analysis includes in the first horizon the raw humus and the upper dark-colored part of the gray layer, or A_1 horizon. In none of the other soils was the raw humus analyzed.

The signs *a*, *b*, *c*, and *d* used in the chemical-analyses tables throughout the ATLAS indicate (*a*) whole-soil, oven-dried at 110° C.; (*b*) whole-soil, calculated to mineral constituents only; (*c*) colloid, oven-dried at 110° C.; (*d*) colloid, calculated to mineral constituents only.

TABLE 2.—*Composition of Becket fine sandy loam, Washington, Mass.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
35887	A_1	0–6	[a] 52.95	0.66	1.08	7.04	0.01	0.90	0.15	2.06	0.40	0.13	0.36	34.40	99.84	1.04	------
			[b] 80.71	1.00	1.64	10.73	.01	1.37	.22	3.14	.60	.19	.54	------	100.15	------	------
			[c] 10.58	.49	3.64	5.99	.02	.65	.31	.49	.25	.31	.99	75.87	99.51	------	------
			[d] 43.84	2.03	15.10	24.80	.08	2.69	1.28	2.03	1.03	1.28	4.10	------	98.26	------	------
35888	A_2	6–11	[a] 83.32	.90	1.69	6.73	.01	.54	.18	2.89	.46	.04	.13	2.75	99.64	.05	------
			[b] 85.67	.92	1.73	6.92	.01	.55	.18	2.97	.47	.04	.13	------	99.59	------	------
			[c] 38.39	1.48	5.55	20.26	.02	.40	1.03	2.51	.24	.25	.23	29.25	99.61	------	------
			[d] 54.30	2.09	7.84	28.70	.03	.57	1.45	3.54	.34	.35	.32	------	99.53	------	------
35889	B_1	11–13	[a] 69.60	.79	3.99	9.61	.01	.65	.33	3.41	.46	.08	.20	11.25	100.68	.14	------
			[b] 78.42	.89	4.49	10.83	.01	.73	.37	3.84	.52	.09	.23	------	100.42	------	------
			[c] 13.40	.90	22.38	12.02	.10	.32	.65	.83	.12	.60	.44	47.90	99.66	------	------
			[d] 25.72	1.73	42.95	23.06	.19	.61	1.24	1.59	.23	1.15	.84	------	99.31	------	------
35890	B_2	13–24	[a] 72.67	.70	3.58	10.32	.02	.62	.41	3.45	.67	.08	.14	7.27	99.93	.09	------
			[b] 78.39	.75	3.86	11.12	.02	.66	.44	3.72	.72	.09	.15	------	99.92	------	------
			[c] 21.56	.74	13.02	20.06	.06	.16	1.18	1.98	.28	.37	.35	39.78	99.54	------	------
			[d] 35.80	1.49	21.60	33.30	.10	.26	1.96	3.29	.46	.61	.58	------	99.45	------	------
35891	C	24–36	[a] 77.86	.53	3.15	10.00	.03	.54	.48	3.79	.55	.08	.13	2.54	99.68	.02	------
			[b] 79.83	.54	3.23	10.26	.03	.55	.49	3.88	.56	.08	.13	------	99.58	------	------
			[c] 34.31	.72	11.60	27.55	.01	.17	2.10	4.10	.25	.18	.19	18.82	100.00	------	------
			[d] 42.18	.88	14.24	33.80	.01	.21	2.58	5.02	.30	.22	.23	------	99.67	------	------

[1] Collected by W. J. Latimer.
[2] Analyzed by G. Edgington and G. J. Hough.

TABLE 2.—*Composition of Becket fine sandy loam, Washington, Mass.*—Continued

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
35887	A_1	0- 6	3.1	10.5	8.2	25.3	22.0	27.1	3.8	100.0
35888	A_2	6-11	2.6	5.9	7.2	23.2	18.3	33.8	7.0	98.0
35889	B_1	11-13	2.5	5.8	7.4	23.8	18.4	31.6	10.6	100.1
35890	B_2	13-24	3.3	5.8	7.3	22.5	19.5	32.0	9.5	99.9
35891	C	24-36	3.4	6.8	8.4	25.8	19.1	26.2	8.9	98.6

[3] Analyzed by L. T. Alexander and H. W. Lakin.

TABLE 3.—*Chemical composition of Caribou loam, Houlton, Me.*[1] [2]

Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*Per cent*	*P. ct.*	*P. ct.*	*Per cent*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per cent*	*P. ct.*	*Per cent*	*P. ct.*	*P. ct.*
A_2	1½- 4	[a]79.11	0.85	1.12	9.57	0.01	0.20	0.44	1.32	1.20	0.11	Trace.	6.07	100.00	0.12	------
		[b]84.25	.90	1.19	10.19	.01	.21	.47	1.41	1.28	.12	Trace.	-------	100.02	------	------
B	4- 8	[a]63.60	.82	5.11	12.71	.03	.19	1.06	1.37	1.32	.10	0.04	13.65	100.00	.26	------
		[b]73.66	.95	5.92	14.72	.03	.22	1.23	1.59	1.53	.12	.05	-------	100.02	------	------
C_1	8-12	[a]66.71	.82	5.10	14.00	.04	.13	1.48	1.70	1.39	.07	.02	8.54	100.00	.15	------
		[b]72.95	.90	5.58	15.31	.04	.14	1.62	1.86	1.52	.08	.02	-------	99.99	------	------
C_2	18-36	[a]67.38	.81	5.82	14.72	.10	.14	1.93	2.24	1.58	.06	Trace.	5.30	100.08	.07	------
		[b]71.15	.85	6.14	15.54	.10	.15	2.03	2 36	1.66	.06	Trace.	-------	100.04	------	------

[1] Collected by L. A. Hurst. [2] Analyzed in the division of soil chemistry, Bureau of Soils, Mar. 22, 1918.

The podzolic character of the profile is brought out in each of the analyses by the high content of silica and low content of alumina, iron oxide, and organic matter in the A_2 horizon and the reverse condition in the B horizon. The content of these constituents in the C horizon varies with the character of the parent material. In some cases that of silica is higher than in the B horizon and in some lower, depending on the content of silica in the original material from which all the horizons were developed. The concentration of organic matter in the B horizon, constituting the orterde, is shown both in the high loss on ignition in this horizon and the high content of nitrogen. In Becket fine sandy loam (Table 2), the percentage of organic matter in the B horizon is about 3.0, that in the A_2 horizon, or bleicherde, is about 1.0. This relative percentage in the two horizons is about the same in Caribou loam (Table 3) also. In the latter the percentage of alumina in the B horizon is 14.72, but in the A_2 horizon it is only 10.19, an apparent increase in the B horizon of about 50 per cent. In iron oxide the apparent increase in percentage in the B horizon over that in the A_2 horizon for the same soil is from 1.19 to 5.92, about 400 per cent increase.

Ontonagon silt loam has developed from reddish lake-laid silty clays and has developed the Podzol profile slowly because the material is heavy. The concentration of organic matter expressed in "loss on ignition" in Table 4, in the B horizon is small in amount but definite. There is also an apparent concentration of both iron oxide and alumina when compared with A, but actually a lower percentage than in C. The concentration of CaO in the organic matter, the A_0 horizon, is well defined.

TABLE 4.—*Composition of Ontonagon silt loam, Union Bay, Mich.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
301601	A_1	0- 3	[a]32.30	0.16	0.98	3.16	0.02	0.95	0.02	0.89	0.49	0.01	0.25	60.48	99.71	0.986	------
			[b]81.74	.40	2.48	7.99	.04	2.40	.05	2.25	1.24	.03	.63	-------	99.25	------	------
301606	A_2	3- 8	[a]82.84	.91	1.84	7.56	.02	.30	.08	2.06	1.49	Tr.	.04	2.92	100.06	.062	------
			[b]85.30	.94	1.89	7.78	.02	.31	.08	2.12	1.53	Tr.	.04	-------	100.01	------	------
301607	B	8-24	[a]75.33	.94	3.41	10.42	.05	.84	.71	2.20	1.76	.02	.06	3.91	99.65	.062	------
			[b]78.38	.98	3.55	10.85	.05	.87	.74	2.29	1.83	.02	.06	-------	99.62	------	------
301608	C	24-40	[a]70.75	.80	4.72	13.32	.07	.80	1.50	3.34	1.37	Tr.	.05	3.62	100.33	.022	------
			[b]73.41	.83	4.90	13.82	.07	.83	1.56	3.47	1.42	Tr.	.05	-------	100.36	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
301601	A_1	0- 3	0.6	22.0	7.3	32.1	5.7	14.8	17.4	99.9
301606	A_2	3- 8	.7	.7	.4	1.8	10.7	78.6	7.0	99.9
301607	B	8-24	.2	.4	.4	2.4	28.2	57.5	10.6	99.7
301608	C	24-40	.4	1.6	2.3	14.0	15.3	38.3	28.1	100.0

[1] Collected by W. D. Lee. [2] Analyzed by G. Edgington. [3] Analyzed by A. A. Riley.

TABLE 5.—*Composition of Hibbing loam, Hibbing, Minn.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28514	A_2	0- 4	[a]77.89	0.69	1.82	9.52	0.02	1.39	0.45	2.11	2.53	0.15	0.11	3.59	100.27	0.073	------
			[b]80.78	.72	1.89	9.87	.03	1.44	.47	2.19	2.62	.16	.11	-------	100.28	------	------
28515	B	4- 8	[a]72.58	.65	3.44	11.52	.04	1.87	.82	1.43	3.01	.23	.12	4.07	99.78	.090	------
			[b]75.64	.68	3.59	12.01	.04	1.95	.85	1.49	3.14	.24	.13	-------	99.76	------	------
28516	C_1	8-30	[a]71.24	.73	4.39	13.51	.08	1.62	1.26	2.34	2.56	.20	.13	2.67	100.73	.023	------
			[b]73.20	.75	4.51	13.88	.08	1.66	1.29	2.40	2.63	.21	.13	-------	100.74	------	------
28517	C_2	30+	[a]64.05	.80	6.80	15.78	.11	1.67	1.58	1.46	2.67	.18	.10	3.77	98.97	.017	------
			[b]66.56	.83	7.06	16.40	.12	1.74	1.64	1.52	2.77	.19	.10	-------	98.93	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28514	A_2	0- 4	0.6	2.0	2.1	15.6	28.8	44.0	6.8	99.9
28515	B	4- 8	.5	2.0	2.2	15.6	33.1	37.7	8.7	99.8
28516	C_1	8-30	3.0	7.6	5.2	19.7	17.7	37.0	10.1	100.3
28517	C_2	30+	1.4	3.7	2.5	9.4	12.5	37.8	32.6	99.9

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Oct. 13, 1920.
[3] Analyzed by A. A. Riley.

TABLE 6.—*Composition of Taylor clay loam, Itasca County, Minn.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
321502	A_1	3- 4	[a]58.99	0.75	4.50	13.00	0.18	1.57	1.30	2.15	1.18	0.17	0.12	16.53	100.44	0.440	------
			[b]70.67	.90	5.39	15.57	.22	1.88	1.56	2.57	1.41	.20	.14	-------	100.48	------	------
321503	A_2	5-10	[a]73.00	.41	3.38	12.66	.17	1.42	1.05	2.71	1.67	.01	.08	3.64	100.20	.074	------
			[b]75.75	.43	3.57	13.13	.18	1.47	1.09	2.81	1.73	.01	.08	-------	100.16	------	------
321504	B	11-18	[a]65.02	.76	5.34	16.63	.18	1.03	1.66	2.48	1.20	.17	.05	5.70	100.22	.120	------
			[b]68.95	.81	5.66	17.63	.19	1.09	1.76	2.63	1.27	.18	.05	-------	100.22	------	------
321505	C	19-36	[a]53.14	.66	5.26	14.62	.14	7.00	3.72	2.19	1.01	.11	.06	11.20	99.11	.050	7.59
			[b]59.87	.74	5.92	16.47	.16	7.88	4.19	2.47	1.14	.12	.07	-------	99.03	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
321502	A_1	3- 4	0	0.3	0.4	3.0	9.8	39.1	47.6	100.2
321503	A_2	5-10	0	.0	.1	2.1	7.3	76.9	13.6	100.0
321504	B	11-18	0	.1	.2	1.2	8.9	44.1	45.5	100.0
321505	C	19-36	0	.0	.2	.7	4.4	42.4	52.3	100.0

[1] Collected by Mark Baldwin.
[2] Analyzed by G. Edgington, G. J. Hough, and R. S. Holmes.
[3] Analyzed by J. B. Spencer.

Hibbing loam (Table 5) has a higher percentage of loss on ignition in the B horizon than in the A_2 horizon, but the composition of A_1 and A_0 were not determined. It has, however, the typical Podzol profile. There is also a higher percentage of both alumina and iron oxide in B than in A, but as in Ontonagon silt loam the percentage in C is higher than in B. The percentages of alkalies and alkaline earths is high compared with the Ontonagon soil but does not change significantly from horizon to horizon.

Taylor clay loam (Table 6) has developed from calcareous material. Loss on ignition is higher in B than in A_2 but much lower than in C. This is due to the presence of calcium carbonate in the latter, the percentage of CO_2 from carbonates being 7.59. The percentage of MgO is high in C also.

The percentage of alumina in B is higher than that in both A and C, but owing to the presence of carbonates in C this does not necessarily indicate concentration of alumina in B. When the excess of calcium carbonate in C above that in B is calculated out, the percentage of alumina in C is almost exactly the same as that in B.

Beltrami silt loam (Table 7) like Taylor clay loam, has developed from calcareous parent material, the percentage of carbonates in C being twice as high as in the latter. Where the excess of this substance is calculated out, the B and C horizons do not differ widely in their alumina and iron oxide percentages. Horizon B has a higher percentage of loss on ignition than A which in this case includes A_1 and A_2. The high loss on ignition in C is due to the presence of carbonates and not to organic matter.

TABLE 7.—*Composition of Beltrami silt loam, Beltrami County, Minn.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
321207	A	0-10	[a]81.34	0.38	1.77	9.46	0.04	1.74	0.72	2.02	2.00	0.08	0.03	1.18	100.76	0.020	------
			[b]82.98	.39	1.80	9.65	.04	1.77	.73	2.06	2.04	.08	.03	-------	100.80	------	------
321208	B	10-22	[a]66.30	.62	6.38	15.44	.08	1.68	1.66	2.51	1.28	.14	.05	4.55	100.69	.080	------
			[b]69.48	.65	6.68	16.18	.08	1.76	1.74	2.63	1.34	.15	.05	-------	100.64	------	------
321209	C_1	22-30	[a]63.86	.61	4.47	13.34	.08	4.34	2.94	2.30	1.15	.15	.04	7.60	100.88	.050	------
			[b]69.11	.66	4.84	14.43	.09	4.70	3.18	2.38	1.24	.16	.04	-------	100.83	------	------
321210	C_2	30-36	[a]46.77	.34	3.06	9.10	.07	15.25	5.10	1.55	.82	.10	.06	17.83	100.06	.033	15.26
			[b]56.91	.41	3.72	11.07	.09	18.55	6.21	1.89	.99	.12	.07	-------	100.04	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
321207	A	0-10	1.5	6.6	5.2	27.5	24.7	30.3	4.2	100.0
321208	B	10-22	1.3	8.6	6.1	23.6	7.1	29.3	24.0	100.0
321209	C_1	22-30	1.2	6.3	4.9	18.4	9.7	37.4	22.1	100.0
321210	C_2	30-36	1.1	3.5	2.5	11.4	8.4	45.4	27.6	99.9

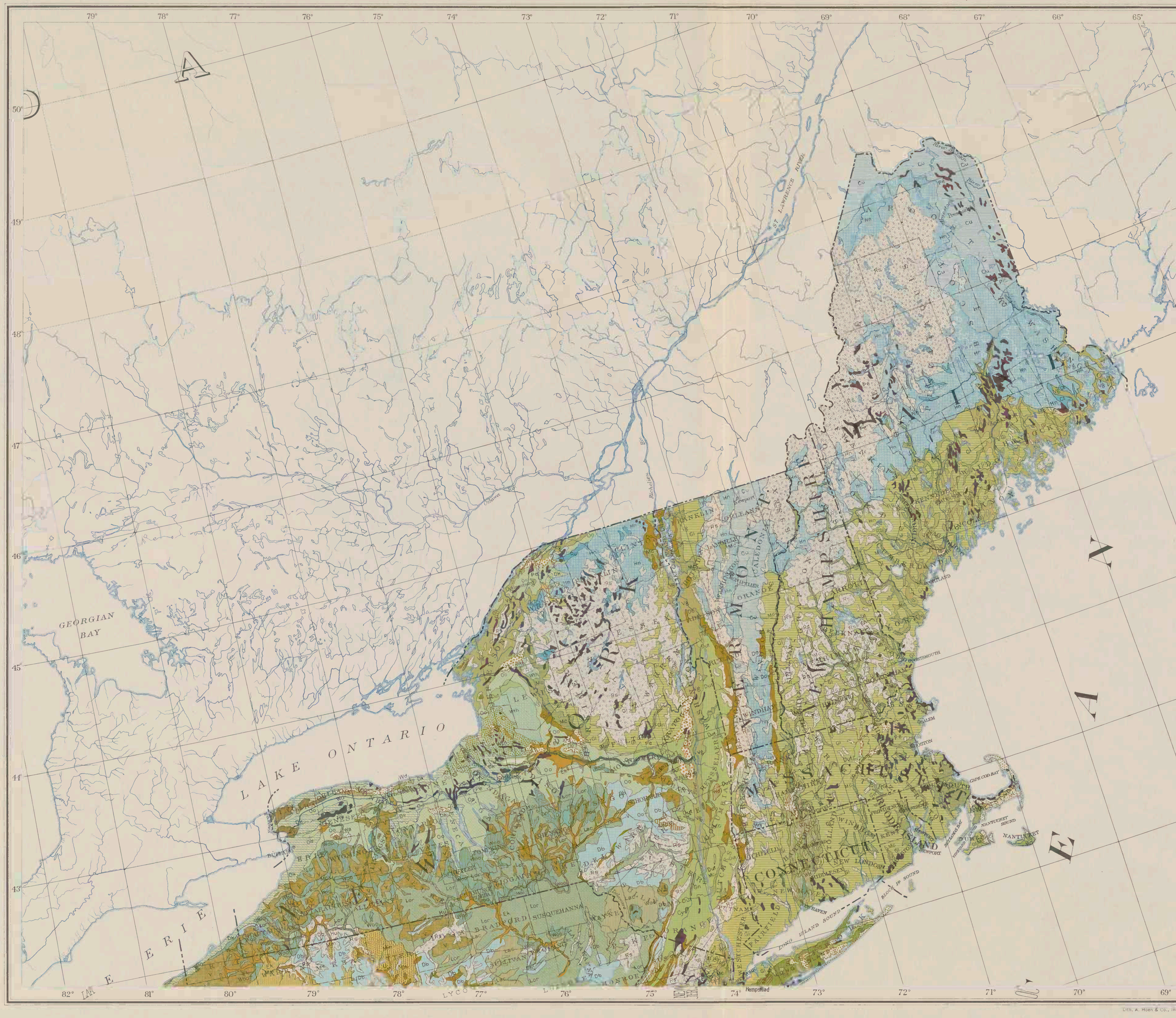
[1] Collected by C. N. Mooney.
[2] Analyzed by G. Edgington and G. J. Hough.
[3] Analyzed by A. A. White.

TABLE 8.—*Composition of Dekalb stony loam, Lycoming County, Pa.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28763	A_2	0-1½	[a]80.71	1.13	2.44	8.23	0.01	0.22	0.32	0.87	0.61	0.03	0.03	6.04	100.64	0.100	------
			[b]85.89	1.20	2.60	8.76	.01	.23	.34	.93	.65	.03	.03	-------	100.67	------	------
28764	B_1	1½-3	[a]66.28	.97	6.16	14.15	.01	.37	.47	1.38	.70	.04	.03	9.82	100.38	.120	------
			[b]73.49	1.08	6.83	15.69	.01	.41	.52	1.53	.78	.04	.03	-------	100.44	------	------
28765	B_2	3-12	[a]67.74	.96	4.92	15.94	.01	.35	.55	1.78	.90	.03	.02	7.57	100.77	.110	------
			[b]73.22	1.04	5.32	17.24	.01	.38	.59	1.94	.97	.03	.02	-------	100.79	------	------
28766	C	12-36	[a]63.86	.96	6.51	19.12	.08	.41	.49	2.49	.73	.02	.01	6.26	100.94	.040	------
			[b]68.10	1.02	6.95	20.38	.09	.44	.52	2.66	.78	.02	.01	-------	100.97	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28763	A_2	0- 1½	1.0	7.9	7.9	16.8	10.1	46.4	10.3	100.4
28764	B_1	1½- 3	1.6	5.7	5.0	14.2	12.8	45.5	15.3	100.1
28765	B_2	3-12	2.0	7.0	4.8	11.2	10.1	49.8	15.6	100.5
28766	C	12-36	3.0	5.2	2.5	9.0	11.1	43.6	25.7	100.1

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough.
[3] Analyzed by V. Jacquot.



Lith. A. Hoen & Co., Inc.

LEGEND FOR THIS SECTION

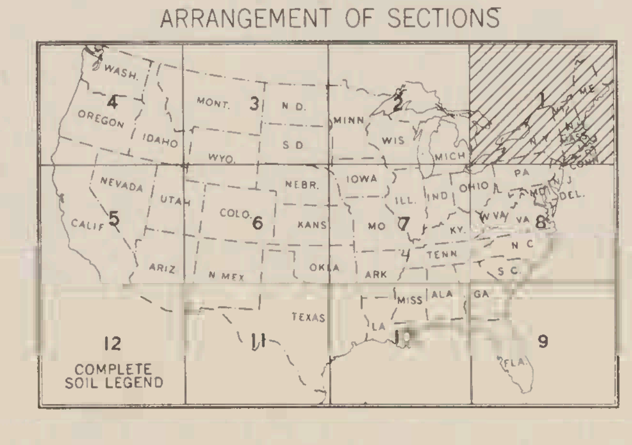
Caribou (Cu)	Elk (Ek)	Miami (Mia)	Wethersfield (Wd)
Chester (Chr)	Genesee (Gn)	Muskingum (Mm)	Wooster (Woo)
Clyde (Cy)	Gloucester (Gl)	Ontario (Oo)	Worth (Wh)
Colton (Ct)	Hermon (Hn)	Penn (Pe)	Marsh and Swamp
Dekalb (Db)	Huntington (Hu)	Sassafras (Ss)	Peat and Muck
Dover (Do)	Lackawanna (Lac)	Upshur (U)	Rough and Stony land (Rs)
Dunkirk (Dk)	Lordstown (Lor)	Vergennes (Vg)	Sand (S)
Dutchess (Dut)	Merrimac (Mc)	Volusia (V)	light Rubicon (Ru)

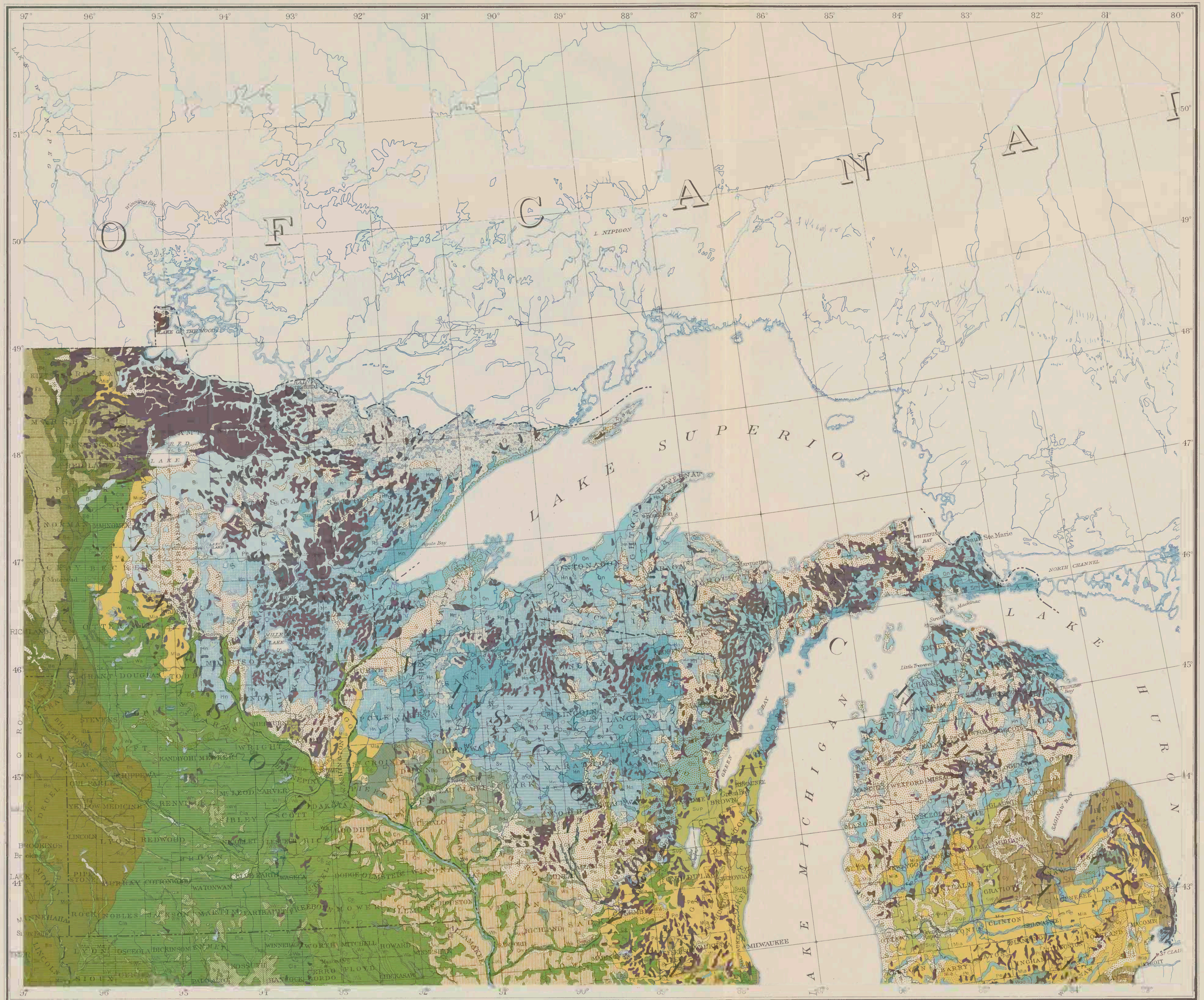
Old apple trees on Gloucester soil, in Worcester County, Mass.

Stone fences on Gloucester sandy loam, Bristol County Mass.

Apple orchard on Dunkirk soil, Monroe County, N. Y.

ARRANGEMENT OF SECTIONS





LEGEND FOR THIS SECTION

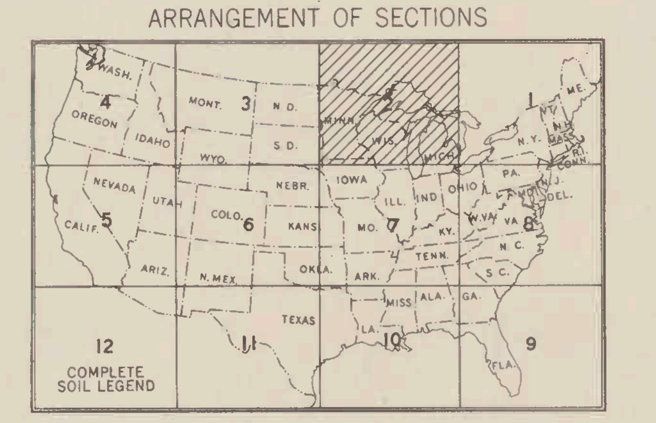
Barnes (Bs), Colton (Ct), Miami (Mia), Summerville (Sm), Bearden (Bk), Fargo (Fa), Moody (Moo), Superior (Sup), Beltrami (Bi), Fox (Fx), Ontonagon (On), Wabash (Wh), Boone (Bo), Genesee (Gn), Plainfield (Pd), Waukesha (Wa), Carrington (Ca), Hermon (Hn), Rubicon (Ru), Webster (Wr), Clarion (Cl), Lindley (Li), Shelby (Sy), Wooster (Woo), Clinton (Cn), Marshall (Me), Sioux (Sx), Sand dark (Sd), Clyde (Cy), Merrimac (Mc), Spencer (Sv), Sand light (S), Gloucester (Gr), Peat and Muck (Pt), Rough and Stony land (Rs), Marsh and Swamp

Landscape of Rockwood sandy loam, Hubbard County, Minn.

Landscape of driftless region of southwestern Wisconsin, Boone soils in Sauk County

Hardwood vegetation on Podzol sand, Chippewa County, Mich.

ARRANGEMENT OF SECTIONS



Lith. A. Hoen & Co., Inc.

Dekalb stony loam (Table 8) has been developed from carbonate-free materials. The percentage of loss on ignition is much higher in B than in A or C, the Podzol profile in this case not being obscured by the presence of carbonates. Alumina and iron percentages are higher in B than in A but lower than in C.

While an apparent increase of alumina in the B horizon is consistent throughout all the samples analyzed, an actual increase has not necessarily taken place. An apparent increase may take place through the removal of alumina from the A_2 horizon even though none of the removed material be deposited in the B horizon. The matter is not cleared up by comparing the percentage in the B horizon with that in C since an apparent concentration in B as compared with C may take place through the removal of silica from the B horizon by decomposition of the silicates instead of by an accumulation of alumina.

A better expression of the changes which have taken place in the horizons through the processes of soil development is obtained by determining the molecular ratio of silica to alumina in each of the horizons after calculating analyses to a mineral basis (free from volatile and combustible matter). This ratio is used by Harrassowitz (*8*) in determining the extent of kaolinitic and lateritic decomposition that has taken place in the decomposition of rocks to clays. In this publication this and two other ratios are used to determine the changes that have taken place in the transformation of the soil material (the decomposed product) into the several horizons of the soil profile.

The silica-alumina ratio of the three principal horizons, A, B, and C, when compared, expresses the result of two changes that may have taken place. One of these is the result of differential decomposition of silicate minerals in the three horizons. After the A horizon has become moderately well defined in its characteristics its silicate minerals presumably are more thoroughly decomposed than those of the other horizons. The progressive decomposition of the latter and the resulting removal of silica will express itself in a different silica-alumina ratio. The other difference is the result of a shifting of alumina from the A horizon and its accumulation in B. This will be expressed in this ratio in all soils that still contain undecomposed minerals, either quartz or silicates, provided there be no change in composition of the alumina compounds at the time of the shift. There seems to be no means, with the data available, of determining how much of the difference in any case is the result of one process and how much the result of the other.

Harrassowitz (*8*) designates the molecular ratio of silica to alumina in either the rock or the decomposed product by the letters ki, that of the sum of the molecules of CaO, K_2O, and Na_2O to those of alumina in the same material by the letters ba. In this discussion a comparison is being made between the several horizons of the soil profile rather than between the rock and the products of its decomposition. In the latter case the extent to which the removal of material has taken place is measured. In this discussion a measure of the changes that have taken place in the transformation of decomposed, or at least unconsolidated, rock materials to soils is being sought. These changes include not merely the loss of materials but also the shifting of materials from one horizon or layer in the soil profile to another.

The molecular ratios of silica to alumina in these several layers are exactly the same as those used by Harrassowitz (*8*), but since they are not interpreted in exactly the same way and are not used for obtaining excatly the same information the ki ratio is here designated as the sa ratio. Another ratio which seems significant in the study of the shifting of materials, which has taken place in the processes of soil development, is that of the molecular ratio of silica in a given material to the iron oxide in the same material. This ratio has not hitherto been used in the interpretation of tables of chemical analyses of soils, but it seems to be of considerable value. It will be used, along with other ratios in the following discussions, and will be designated as the sf ratio.

The molecular equivalent composition in SiO_2, Fe_2O_3, Al_2O_3, and in some cases of the combined alkalies and alkaline earths has been used in the following pages also. In the processes of soil development the most significant changes in the materials concern the sesquioxides, silica, and the alkalies and alkaline earths. This being the case the effect of the processes can best be seen in the relationships to each other of these constituents in the A, B, and C horizons. The molecular equivalent composition, computed to show these changes, has been computed for these three substances only, except in special cases where that of the combined alkalies and alkaline earths is desired. The molecular equivalent figures have not been calculated to 100. The significant matter with regard to them is the relations of these figures for *each substance* in the *several horizons* of the soil and not the interrelations of substances themselves.

Since a low sa ratio in the B horizon and a high ratio in the C can be due either to a more advanced stage of decomposition of the feldspars and the consequent greater loss of silicate silica in the B horizon than in the C, or to a concentration of the alumina in the B horizon through illuviation, practically the same ratio for both horizons shows that neither process has been operating in the Becket profile. (Table 9.) Such eluviation, or translocation of material from the A to the B horizon, as has taken place has affected other constituents rather than the alumina. The complete analysis shows that the B horizon is one of organic-matter concentration when compared with either the A_2 or C horizons.

TABLE 9.—*Becket fine sandy loam, Washington, Mass.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
35888	A_2	6–11	20.50	131.20	0.725	1.422	0.109	0.0678
35889	B_1	11–13	12.30	46.28	.585	1.306	.028	.1062
35891	C	24–36	13.24	65.54	.523	1.300	.020	.1003

The sa ratio indicates that no decomposition of feldspars has taken place in the B horizon since the accumulation of the soil material took place, or during the period of soil profile development, and presumably none of any minerals. The silica-iron oxide or sf ratio shows by the pronounced differences in the three horizons that the translocation of oxide iron has been considerable. This ratio in the three horizons shows a wide difference between the A_2 and B horizons and an important one between the B and C. It is clear from these figures that the Becket Podzol is an organic matter-iron oxide Podzol in which very little shifting of alumina has taken place.

The molecular ratio of the sum of the lime, potash, and soda to the alumina, a ratio used by students of rock decomposition and especially by Harrassowitz (*8*), is suggestive also but not highly important in the interpretation of shifting and accumulation of material, since the concentration of these constituents, in any of the horizons of the soils of the Pedalfer group, is slight and apparently not a consistent process in podzolic development. It is important, however, as an expression of the amount of leaching that has taken place.

Colloid material was extracted from the same samples of Becket fine sandy loam, discussed in the preceding paragraph, by Anderson and Byers (*1*) of the Bureau of Chemistry and Soils, by the methods in general use in this bureau, and subjected to chemical analysis. The results are shown in Table 2. The several ratios, sa, ba, and sf, for the colloid are shown in Table 10.

TABLE 10.—*Colloid of Becket fine sandy loam, Washington, Mass.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
35888	A_2	6–11	3.2	18.33	0.19	0.636	0.035	0.198
35889	B_1	11–13	1.89	1.58	.14	.222	.140	.117
35890	B_2	13–24	1.82	2.75	.14	.357	.082	.196
35891	C	24–36	2.12	3.19	.19	.569	.073	.269

The content of silica in the colloid of the bleicherde, or A_2 horizon, is very high. In the A_2 horizon of the whole soil, sa (Table 9) is about 70 percent higher than in the B horizon. In the colloid, however (Table 10), it is 100 per cent higher. A possible explanation of this relationship is found in the assumption that the colloid of the B horizon has been more thoroughly hydrolyzed and has lost, therefore, a greater proportion of its silica than has that in the A horizon. This is suggested by Anderson and Byers (*1*). Another possibility is the presence in the A_2 horizon of a quantity of quartz in particles of colloidal size. This latter is rather confirmed by comparing the ratios (sa) in the B_1 and C horizons. These are so nearly the same as to suggest strongly the conclusion that the B horizon is not only one lacking alumina accumulation, but they also suggest that the colloid in the C horizon is in essentially the same stages of decomposition as in the B horizon, so far as the aluminum silicate minerals are concerned. This is the same conclusion as that drawn from the relationships of these horizons based on the composition of the whole soil.

The ba figures for the three horizons indicate a lower content of alkalies and calcium (magnesia not included in the computation) in the B horizon, than in A_2 or C. These constituents in A_2 and C are contained partly in undecomposed primary minerals and are partly absorbed on colloids. B is a horizon of high organic matter and iron hydroxide and has not absorbed these elements strongly.

The sf ratios for the three horizons have the same relative succession or order of values as in the whole soil, but the proportional values in the several horizons are not identical. The succession of values for the three successive horizons of 18, 1.6, and 3.2 in the colloid, compared with 131, 46, and 65 in the soil, indicate a much higher concentration of iron oxide in the B horizon of the colloid than in that of the whole soil. It is to be expected that this accumulation would be shown more clearly by the colloid composition than by that of the whole soil since presumably shifting of material has concerned the colloid mainly. The ratios for the colloid point to the same conclusion as those in the whole soil, namely, that Becket fine sandy loam is a Podzol in which translocation of material from the A to the B horizon has affected the iron oxide and organic matter mainly and the alumina to a very slight extent.

In Caribou loam (Table 11) the ratios show greater differences than in the Becket soil but they are mainly between the A_2 and B horizons. In the B and C_2 horizons, sa is 8.50 and 7.78, respectively, the difference being about the same as in the same horizons of the Becket soil but in the opposite direction. The B horizon has a higher figure for sa than the C. The difference is so small, however, that no definite conclusion can be drawn. It is possibly merely a small difference in character of material. The difference between the A_2 and B horizons is much larger and indicates a concentration of silica, due to the removal of feldspathic decomposition products through eluviation or to the presence of a sandy surface cover. The latter is improbable. The explanation seems to lie in the removal of alumina from the A horizon, but the B horizon seems not to have received it. In the same way the silica-iron ratios show the removal of the iron from the A_2 horizon, but the ratio in the B horizon does not indicate any concentration over that contained in C_2. The Caribou loam seems to be a humus Podzol, not, however, the kind defined by Frosterus (*6*), in which both iron and alumina have been removed from the A horizon, but the removed material has not been deposited in the B horizon.

TABLE 11.—*Caribou loam, Houlton, Me.*

Horizon	Depth in inches	Ratios			Molecular equivalent composition		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
A_2	1–4	14.05	187.62	0.394	1.402	0.0074	0.0999
B	4–8	8.50	32.97	.315	1.227	.0371	.1444
C_2	18–36	7.78	30.70	.358	1.185	.0038	.1525

The Hibbing loam profile is unusual because of the presence of an indurated layer below 30 inches. This is not the parent material of the A_2 and B horizons so that comparison of the composition of the latter with this horizon would not be significant. The high content of alumina and iron oxide in this layer is not significant in soil development. The ratio (Table 12) in this indurated horizon shows a much higher content of alumina than in the A_2 or B horizons. The silica-iron oxide ratio shows a high content of iron oxide also.

TABLE 12.—*Hibbing loam, Hibbing, Minn.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
28514	A_2	0–4	13.91	113.30	0.933	1.345	0.0118	0.096
28515	B	4–8	10.70	55.84	.794	1.261	.0225	.117
28517	C_2	30+	6.90	24.98	.572	1.109	.0442	.160

Beltrami silt loam has developed from calcareous material. The Podzol profile is well developed, but the sa ratios for the A, B, and C horizons (Table 13) fail to show any significant concentration of alumina in the B horizon above that in the C. The figures for the silica-iron oxide ratios, however, show a significant concentration of iron oxide in the B horizon. The A horizon has a much higher percentage of silica than is in the others. Since the sa ratios show this silica concentration as well as the ratios for the iron oxide, it is apparent that alumina has been removed from the A horizon without any corresponding increase in the B.

TABLE 13.—*Beltrami silt loam, Beltrami County, Minn.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
321207	A	0-10	14. 56	121. 00	0. 914	1. 371	0. 0113	0. 0942
321208	B	10-22	7. 30	27. 97	. 511	1. 158	. 0412	. 1587
321210	C_2	30-36	8. 73	40. 54	3. 380	. 947	. 0233	. 0108

THE GRAY-BROWN PODZOLIC SOILS

These are soils in which the podzolic process has been the dominant one in their development. In these soils, as in the true Podzols, the process is primarily one of leaching, developing eventually an acid reaction in the soil and a solum in which readily soluble salts and a considerable percentage of the bases (alkalies and alkaline earths) have been removed. An eluviated A horizon and an illuviated B horizon have been developed. The profile is not identical with that of the Podzols, but the difference is one due to the degree of the operation of the podzolic process mainly, but recent work by Anderson and Byers has confirmed a former brief statement by Gedroiz that in the Podzols a breaking up of the silicates by soil-developing processes has taken place. No such silicate decomposition has been shown to have taken place in the Gray-Brown Podzolic soils region. The virgin profile in no case includes a thick layer of raw humus. There is always an accumulation of organic matter on the surface but it rarely amounts, in the United States at least, to more than an inch or two and is better decomposed than is the true raw humus overlying the well-developed Podzols. It is apparent that in the United States this humus rarely develops into what is called mull in Europe. It is not usually thoroughly decomposed into black granular colloidal material, but is somewhat more closely related to raw humus in inherent characteristics than to mull. The bleicherde, or A_2 horizon, is not white or light gray as in the Podzols but is grayish brown or pale yellow and is usually not so thoroughly eluviated. A thin layer, impregnated with organic matter (horizon A_1), constituting the upper part of the mineral soil is thicker than the corresponding layer in the Podzols, and it may have a faintly developed granular structure. The rest of the A horizon is structureless but has a laminated arrangement in the undisturbed soil.

The B horizon is heavier in texture than horizon A, with an apparent accumulation of iron oxide and alumina but none of organic matter. In no case in the United States has the B horizon been indurated to an ortstein. The profiles are similar apparently to the eisenpodzol profile as described by Frosterus (*6*). It is apparent that in this country we have no humous Podzols, such as are described by the same author, or if so they have a limited distribution in the neighborhood of swamps and lakes in the Podzol region. The true Podzols of the United States are well-drained soils in which iron oxide, alumina, and organic matter are present in higher percentages in horizon B than in A or C, whereas in the Gray-Brown Podzolic soils iron oxide and alumina only have been involved in apparent accumulation in the B horizon.

This group of soils is defined on the basis of soil characteristics only and without reference to geographic distribution, yet they occupy a well-defined region of the United States, one much larger than that occupied by the Podzols. The region includes the midlatitude belt of the United States extending from the Atlantic coast westward to the prairies in western Indiana, with a narrow tongue extending northwestward across Wisconsin into Minnesota, and another across western Kentucky and Tennessee into the Ozark region of southern Missouri. A great many small areas, originally covered with forest, scattered through the prairie region of the middle West, always in areas of uneven relief, are covered by members of this group also. The northern boundary is also the southern boundary of the Podzol region but, as in nature generally, no sharp boundary line exists. The true boundary is a zone of gradation in which, from north to south, the dominant Podzols become the dominant Gray-Brown Podzolic soils. On its south side the region is bounded by the common boundary between it and the Red and Yellow soils. This line runs, in general, from the mouth of Chesapeake Bay southwestward across the Appalachian region in western North Carolina, across Tennessee and the Ozark region and thence curves northward with the eastern boundary of the prairies to northwestern Minnesota. (See pl. 2.)

This area was occupied, before it was cleared for agricultural use, by deciduous forest, with practically no admixture of conifers. The precipitation is essentially the same as in the Podzol region.

The environmental conditions prevailing in the Podzol and the Gray-Brown Podzolic regions are not widely different. In both, the rainfall is high, ranging from 30 to 40 inches, both were forested, the former with both conifers and deciduous species, the latter with deciduous species, mainly oak. The prevailing temperatures are considerably higher in the Gray-Brown Podzolic region than in the Podzol region. This is probably the most important difference between them. The higher temperature has operated directly as a soil-developing factor and indirectly through its influence on air humidity and evaporation. The existence of the Podzol profile beneath deciduous forests and the presumption that it developed under this influence suggests that the difference of forest character has not been all powerful. The same kinds of parent materials occur in both regions, but the Podzol profile, as shown by its occurrence in full development in New Jersey and Maryland, extends farther southward into the general region of the Gray-Brown Podzolic soils on sands than on other parent materials. This suggests that one of the differences between the Podzol and the Gray-Brown Podzolic profile is a difference in the extent of development of a single process.

The average summer temperature in a belt running across the central part of the Podzol region in the United States is about 65° F., and the average winter temperature is about 15°. The average summer temperature across the central part of the area of Gray-Brown Podzolic soils is about 73° and the average winter temperature is about 32° except east of the Appalachians, where it is about 35°.

In addition to the main region, already described, in which these soils are dominant, and the smaller areas within the prairies, large areas of soils in the Pacific northwest seem to belong to the group. Smaller and less continuous areas lie in the Rocky Mountain region. In all parts of the West and Northwest the soils, although belonging apparently to this and the next group to be described, are not identical with their eastern relatives. In general the degree of podzolization, measured by the development of a light-colored A horizon, is not so complete. The A horizons are brown rather than decidedly gray or yellow as in the East, and the illuviated B horizon is not so well marked. These soils seem to belong, in stage of podzolic development, nearer to the stage occupied by the Brown soils of Ramann [11] than do the true Gray-Brown Podzolic soils. The latter, among students who have given most attention to them, are now defined as still in a stage of practically complete saturation by bases. They have developed under forest cover but have not yet been podzolized or at least very faintly. The soils of the Northwest seem to have passed this stage but have not yet reached that occupied by the Gray-Brown Podzolic soils.

THE MEMBERS OF THE GROUP

A large number of soil series have been differentiated in the detailed soil mapping within the region of Gray-Brown Podzolic soils. The whole region has not yet been mapped, but it is probable that nearly all the well-defined series occurring in it have already been defined. The number stands now at somewhat more than fifty.

All the soils within this region, except those so young that no profile development has taken place, have profiles with the same general characteristics as those already described in comparing these soils with the Podzols. The soil series of the group have been differentiated on the basis of all those features expressing differences in stage of development, character of the parent material, differences in drainage (both surface and subsoil), and differences in texture.

The chemical composition throughout the region has the same pattern. The chemical profile consists of a thin surface layer with a high content of organic matter, a relatively high content of calcium, and to a less extent of potash and phosphoric acid, and a low content of iron oxide and alumina. In terms of the physical and morphological profile, this layer constitutes the upper part of the A horizon. It is underlain by the lower part of the A horizon which, as in the Podzols, has a high content of silica and a low content of practically all the other constituents. The B horizon has a high content of iron oxide and alumina, a higher content of potash than the A horizon, while the percentages of the rest of the alkalies and alkaline earths and of the phosphoric acid may be larger or smaller.

Since the several soil series within the group have been differentiated on the basis of several characteristics, including the character of the parent material, it is evident that the distribution of these series will have a certain parallelism with the distribution of different kinds of geologic material. Plate 4 shows the distribution within the United States of different kinds of geologic material expressed in terms of parent materials of the soil. The different kinds of parent material are differentiated on this map on the basis of the processes by which the material was accumulated, the two principal processes of accumulation being deposition and residual decay, while within each of these two main groups differentiations are based largely on the mineralogical character of the material. An examination of this map will show a certain correlation between the distribution of different kinds of parent materials and the distribution of soil series on the large soil map (pl. 5, secs. 1 to 12), while there is no such correspondence between the distribution of the geologic formations and various members of the groups shown on Plate 2.

SOILS OF THE COASTAL PLAIN

SASSAFRAS AND ASSOCIATED SOILS

In the eastern part of the United States where the relief and distribution of geologic formations have been influenced to a very great extent by the crustal movements which formed the Appalachian Mountain system and by the erosion to which the region was subjected contemporaneously and later, the geologic formations are distributed in belts which run in a general northeast and southwest direction. It is evident that the distribution of soil series will have the same trend. In addition to the old rocks, involved in the Appalachian folding and premesozoic erosion, a belt of unconsolidated sand, clays, and greensands occupies a strip along the coast, from Cape Cod to Texas. It ranges in width from a mere strip to several hundred miles, but in the Chesapeake Bay region it attains a width of less than 75 miles, narrowing to a point at New York City. By including Long Island, the islands of the coast of southeastern New England, and Cape Cod, the belt continues to Provincetown, Mass. Pedologically these islands and Cape Cod belong in the belt, but geologically they are different from a considerable part of the belt south of New York. This belt of young, unconsolidated deposits is called the coastal plain. This designation, however, is not applied to Long Island, Cape Cod, and the islands of southeastern Massachusetts. In this belt south of Massachusetts, members of the Sassafras series are the dominant soils. Collington soils constitute an important associated series in New Jersey and Maryland. Associated with these two series are considerable areas of Leonardtown, Myatt, and Portsmouth soils. Other soil series are associated with them, but they occur in relatively small areas and cannot be shown on the map. The details regarding these minor series can be obtained from the detailed soil survey reports covering various parts of this region.

The Sassafras soils are the most important within this belt and extend, as shown on the map, from Long Island to the mouth of Chesapeake Bay. They are typical members of the Gray-Brown Podzolic group and, because of the rather sandy texture of the parent material, their profile is well developed. The surface is covered, within the forest, by the usual mat type of raw humus. The upper 3 inches of the mineral soil is darkened by the incorporation of a small amount of organic matter, but the texture of the mineral material is coarse, consisting mainly of sand. The color is dark gray, the sand grains usually being gray and visible within the dark mass. Beneath this, extending to a depth of about a foot, is a very pale yellow or grayish-yellow light loamy sand, structureless and well leached, as is shown by the chemical composition.

[11] These soils constitute a group established by the late Dr. E. Ramann of Munich. They were not fully defined by him but at a later date Stremme and Aarnio defined them as neutral, brown forest soils or soils in which podzolization had not taken place. Such soils occur in small areas among the Gray-Brown Podzolic soils of the United States but not in large continuous areas. According to the American point of view they are potential Gray-Brown Podzolic soils not yet podzolized.

These two layers constitute the A horizon. Its thickness varies from 6 inches to more than a foot, depending on the texture of the material and the relief of the surface on which it lies. It is underlain by the B horizon, which is yellowish with a faint reddish shade, heavier in texture than the A horizon, consisting of sandy clay but structureless or practically so. It is heaviest at the top, and gradually becomes lighter in texture downward as well as somewhat lighter in color. The layer ranges up to somewhat less than 2 feet in thickness, and it passes downward into grayish or faintly reddish sandy material, generally lighter in texture than the B horizon. This soil occupies the rolling, well-drained uplands of the coastal plain from the mouth of Chesapeake Bay northward into Long Island where the soil has developed from material heavier than sand or loamy sand and contains no marl, either calcareous or glauconitic. It occupies also the smooth terraces of the region where they are underlain by gravel at a depth of 3 or 4 feet. The lighter textured material beneath the solum supplies good underdrainage, and it is to this condition that the faint reddish color of the B horizon may be ascribed.

A number of imperfectly developed soils derived from the same parent material are associated with the Sassafras soils. These consist in part of poorly drained soils occupying the flat interstream areas shown on the soil map (pl. 5, secs. 1 to 12) as Portsmouth, but they also include members of the Keyport and other less important series, as well as areas of peat and muck. Another group of soils, designated on the map as Myatt, consists of soils which have developed under alternating wet and dry conditions. They are wet in winter and spring and dry in summer. These soils are light in color and have a much heavier B horizon than the normally developed Sassafras soils. The true Myatt soils are associated with the Red and Yellow soils and occur in the southeastern part of the United States but on the soil map (pl. 5, sec. 8) the imperfectly drained soils closely associated with the Portsmouth soils in the Chesapeake Bay region, subjected to alternating wet and dry conditions, are shown as Myatt. In detailed mapping these soils are identified as members of the Elkton series.

In southern Maryland, occupying flat areas on uneroded parts of the coastal plain, a soil has developed a normal profile to a depth of about 24 inches or, in other words, normal A and B horizons, but in the lower part of the B horizon or the upper part of the C horizon the material has become indurated into a hardpan. The A horizon is paler in color than the corresponding horizon in the Sassafras soils, while the B horizon is not so red and is usually somewhat heavier in texture. This is the Leonardtown silt loam.

The soils of the Collington series are associated with those of the Sassafras as an important series of the Chesapeake Bay region. (Fig. 8.) They have in general the profile of the soils of the group, but being derived from material heavier in texture than the mixed sand and clay from which the Sassafras soils have developed, the soils are heavier, taken as a whole, and stronger in color than the latter. They have not been so thoroughly leached or so thoroughly eluviated. The A horizon is not so pale in color nor so light in texture. The dark-colored layer in the upper part of the A horizon is thicker, as a rule, and constitutes a larger proportion of the A horizon than in the Sassafras soils. The B horizon is heavier than the B horizon of the Sassafras soils, but the difference in texture between the A and B horizons is not so great as in the Sassafras, and the color of the B horizon is dominantly brown rather than reddish brown as in the Sassafras. The C horizon is made up of greensand marls or glauconite.

The differentiation of the Collington soils from the Sassafras is based partly on the character of the parent material, but even if the soil surveyor should not see the parent material he would not fail to differentiate the Collington soils on the basis of their solum characteristics alone. These characteristics consist of less extreme development of all of the features than is characteristic of the Sassafras soils. Being heavier in texture than the latter they are more productive for grain crops.

It has already been stated, in the discussion of the character and distribution of the Podzols that the soils developed on sands in eastern New Jersey, Long Island, the islands of southeastern Massachusetts, and possibly also a large part of Barnstable County, Mass., are Podzols. They have already been described, therefore, on page 17.

PENN AND ASSOCIATED SOILS

The piedmont plateau consists of a belt of dissected plateau, developed mainly on ancient crystalline rocks, lying parallel to and immediately west of the coastal plain. The belt runs from the southeastern part of New York State southwestward to Alabama. It crosses the east-west belt occupied by the Gray-Brown Podzolic soils and within the boundaries of the latter the soils on the piedmont plateau belong to the Gray-Brown Podzolic group.

Although the dominant rocks in the plateau are ancient crystallines, other rocks occur, and in the northern part of the belt, that part included in the region of Gray-Brown Podzolic soils, other rocks than ancient crystallines are dominant. Within the ancient crystallines themselves rock character differs greatly and this produces soils belonging in different series, but in that part of the plateau now being considered the other rocks referred to, consisting of sandstones, shales, limestones, and igneous rocks, are responsible for still wider soil differences than those within the crystallines. The most important sandstone and shale rocks within the northern part of the piedmont plateau are the Triassic red shales and sandstones.

An important part of the piedmont region in Pennsylvania, New Jersey, and New York is underlain by red shales and sandstones. Southward from the main part of the area in Pennsylvania, New Jersey, and southern New York a belt stretches across Maryland and Virginia into North Carolina. Another important area occupies the Connecticut Valley lowland of Massachusetts and Connecticut.

These rocks, like all shales, disintegrate slowly, and as a consequence the layer of disintegrated and decomposed material overlying the rock constituting the soil material is, over considerable areas, thin, and the reddish rock color still persists in it. Under these conditions the layer of soil material is too thin for the development of the normal A and B horizons of the Gray-Brown Podzolic soils. In many places it is thick enough for the development of an A horizon only. A yellowish-brown A horizon has developed, but the fact that the soils of plowed fields are almost universally somewhat red in color shows that it is not so thick as the depth of plowing. Practically no B horizon has developed. The disintegrated red shales or the shales undisintegrated lie beneath the A horizon.

Soils of the character just described prevail throughout the region on slopes as well as on large areas of smooth relief, especially in New Jersey. In Pennsylvania the proportional area occupied by such soils seems to be smaller than in New Jersey. Where the normal Gray-Brown Podzolic profile has developed on Triassic materials either in Pennsylvania or New Jersey the soil colors are paler than in either the Sassafras or Collington soils. The sandy parent materials of both the latter soils and especially of the Sassafras have supplied good underdrainage.

The Penn soils, where shallow, are underlain by the undecomposed shale beneath a thin layer of disintegrated shale, through which water does not percolate rapidly. Where the soil material layer (decomposed material) is thick it may or may not be underlain by shale at a comparatively slight depth, but the material itself is heavy enough to retard percolation. Such areas also usually lie on flat relief where surface drainage is slow. The Penn soils, therefore, are brown or yellowish brown and lack the reddish subsoil color of the Sassafras soils. The red color of the shallow soils of the Penn series is a rock color not a soil color, whereas the reddish subsoil color of the Sassafras soils is a soil color not rock color. The deeply weathered yellow or yellow-brown soils derived from the Triassic shales belong in fact to a different soil series from the shallow red soils, but they have not yet been separated.

From Plainfield, N. J., northward the soil material was accumulated by glacial action, but the material was derived from the local rocks, Triassic red shales and sandstones, and has, in general, characteristics very similar to the materials from the same rocks farther south where the unconsolidated surface material from which the soils have developed was accumulated by decay of the rocks in place. The soils derived from this locally accumulated glacial material in New Jersey and the extreme southern part of New York are mapped as members of the Wethersfield series, together with other series of less importance. The former soils are reddish, like the shallow Penn soils, but the accumulated glacial drift layer is thicker than the layer of residual material south of the glacial limit. The soils in the Connecticut Valley lowland are shown as Wethersfield also, but the true Wethersfield soils in this area are associated with large areas of terrace soils, none of which is shown. It is probable that detailed mapping will finally show that the brown more perfectly developed terrace soils occupy even a larger area than the Wethersfield. The distinguishing characteristics of the Wethersfield soils are faint development of the typical podzolic profile and a reddish color. The latter is a rock color, however, and not a soil color. It has not been derived from weathering in place since the material was accumulated but was present in the rock before the soil material was accumulated.

FIGURE 8.—Hardwood forest on Collington loam, Prince Georges County, Md.

CHESTER AND ASSOCIATED SOILS

The soils of this group include those occurring in the piedmont region of Virginia, Maryland, Pennsylvania, and New Jersey. The designation of the group used here is justified on the ground that the Chester soils have the most fully developed profile of all the soils of the group. Northward the soils of the group gradually merge, through transitional soils not yet carefully studied or given status as independent series, in northern New Jersey with the soils of the New England group described later as soils of the Gloucester and associated soils. The Gloucester and associated soils of southern New England occupy an area much larger than that occupied by the Chester, but they have a profile less fully developed and therefore less characteristic of the normal soils of the Gray-Brown Podzolic group than the Chester soils. The soil-developing forces in New England are less active than in Maryland, and the material was accumulated later.

The Chester soils extend into western North Carolina, but their profiles are not so well developed as in Virginia.

The Chester soils have developed from material accumulated by the decay of the ancient crystalline rocks of the piedmont plateau. (Fig. 9.) They constitute the typical mature Gray-Brown Podzolic soils from this material. The A horizon is light in color and in texture compared with the B horizon. It ranges from light brown to yellowish. The B horizon is heavier in texture and is brown or faintly reddish brown. The percentage of finely divided material, colloidal or otherwise, is greater than in the parent material of the Sassafras soils, and in the eluviation process this has been accumulated in the B horizon. The B horizon thus becomes heavy enough for the development of the characteristic breakage into small angular particles which constitute so important a feature of the well-developed moderately heavy B horizons of the Podzolic soils. The A horizon is essentially structureless where sandy, but where silty the lower part may have a well-defined lamination and the upper part, with organic matter incorporation, may be granular. Where the breakage particles of the B horizon are well defined the color is usually somewhat more intense on the outsides of the particles than on the insides. It is apparent that these breakage lines are lines along which the air and water penetrate the soils, and since these soils are well drained and since the climate is marked by high rainfall and hot summers with periodic drying of the soil to considerable depth, oxidation and dehydration on the outsides of the particles have been more intense than on the insides. The insides of the particles are yellowish brown.

The parent material, or C horizon, consists of disintegrated crystalline rock material from schists, gneisses, or, more rarely, fine-grained slates, usually very loose, containing a considerable amount of undecomposed minerals. In many places it is reddish in color, especially immediately beneath the B horizon, but it becomes yellowish or grayish with depth and finally, within a few feet, grades into the consolidated crystalline rock.

Chester soils constitute the typical mature Gray-Brown Podzolic soils from crystalline rock material, corresponding to the Sassafras soils from unconsolidated sands and clays of the coastal-plain deposits and the Collington soils from greensand marl deposits of the coastal plain. All these soils are members of the same broad group, have fundamentally the same character of soil profile, and have developed under the same climatic conditions and the same forest cover, so that their differences are due largely to differences in character of parent material. The difference between the Sassafras soils and the Chester soils is largely a difference between the amount of clay in the parent material or the amount of minerals which, on decomposition, change to clay.

The piedmont region of Pennsylvania, Maryland, and Virginia is thoroughly dissected and includes no poorly drained areas. It contains imperfectly developed soils, however, but these are soils which occur on slopes where the material has not been allowed to lie in place long enough to develop a normal soil profile. In the Chesapeake Bay region of Maryland and Virginia the Manor soils are of this character. On very small areas, however, where the relief is flat and where the drainage is less perfect than in the rolling areas where the normal Chester profile has developed, soils have developed which have a profile very similar to that of the Leonardtown soils associated with the Sassafras. These soils have not yet been named but they are known to occur and may be considered as Leonardtown-Chester soils.

HAGERSTOWN AND ASSOCIATED SOILS

In Maryland and Pennsylvania and to less extent in Virginia (fig. 10), there are areas of considerable size in the piedmont belt, in which, through the folding which produced the mountains originally, limestone beds were folded down into synclines to such depth that subsequent erosion did not remove them entirely. These piedmont areas, therefore, are underlain by limestones, and the soils have developed from the products of the disintegration and decomposition of the limestones which are identical in character with, and presumably are merely eastward extensions of the limestones underlying the great valley of the Appalachian region, extending from the St. Lawrence River southwestward to Alabama. The Great Valley consists of a lowland belt lying immediately west of the Blue Ridge and is separated from the piedmont region by that physiographic feature.

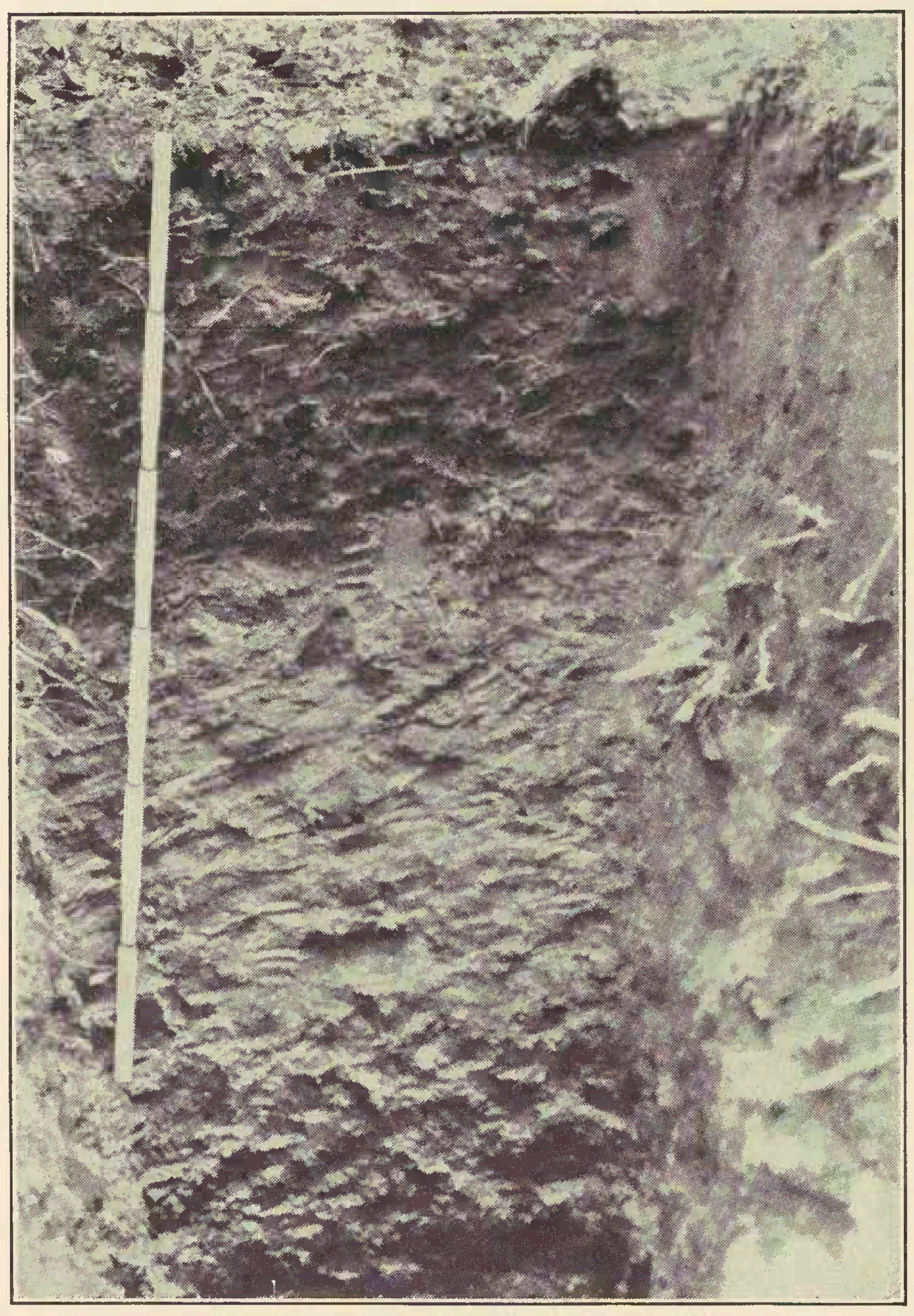


FIGURE 9.—Profile of Chester loam, Howard County, Md., showing indurated (gray) horizon.

The Great Valley, therefore, and the limestone basins in the piedmont region having soils developed from the same kinds of materials accumulated by the same process, that of residual decay, from the same kinds of rocks, have developed under the same forest cover and the same climatic conditions. They have developed also on the same kind of relief, and have attained, in general, identical stages of development. The soils are well drained and are normal members of the Gray-Brown Podzolic group. The parent material, consisting only of fine-grained material, originally incorporated with the lime carbonate of the limestones, is heavier in texture than the constituents of the soil material of the piedmont region and of the coastal plain. It consists of silt and clay, together with an extremely small amount of very fine grained sand, the clay constituent in the parent material being considerable. The surface soil assumes the usual light-colored, or gray, A horizon. The B horizon is heavier in texture than the A, though everywhere friable, and its color is brown, with a well-defined reddish shade. The material of the B horizon being heavy breaks into the usual angular particles similar to those in the B horizon of the Chester soils, but they are better defined. The outsides of the particles, like those in the Chester soils, are stronger in color than the insides. Partly on account of the rolling surface on which these soils occur, the A horizon has been removed by erosion over large areas, especially where the soils have been cultivated for a long time. The farmer, in such cases, is now cultivating the B horizon. On the detailed soil maps of the region, Hagerstown silt loam is the soil which still retains the A horizon, and Hagerstown clay loam is the soil from which the A horizon has been removed. On the large soil map (pl. 5, sec. 8) no differentiation of the soil by texture is attempted. The soils are identified as members of the Hagerstown series. The important areas in the piedmont plateau are the Lancaster County area in Pennsylvania with a narrow extension northeastward to Norristown, Pa., and another extending southwestward by York, Pa., across Maryland, with minor breaks, and into northern Virginia.

The broad lowland belt called the Great Valley is not underlain entirely by limestones. It is underlain by rocks that are relatively less resistant to erosion than those of the Blue Ridge on its southeastern side and the Appalachian ridges of sandstone on the northwestern side.

The northwestern half of the Great Valley in Pennsylvania and important belts elsewhere are underlain by shales. These rocks are only slightly more resistant to erosion than the limestones. They have been worn down to a lowland standing slightly higher than the area underlain by limestones, but they constitute a part of the Great Valley.

These rocks have disintegrated and decomposed into silt and clay, but as a rule the layer overlying the shales is thin, somewhat like the layer overlying much of the Triassic shales in the piedmont plateau. These soils where mature are yellowish, especially in the subsoil, and they have grayish-brown surface soils. Not much work has been done on them in recent years. They have been given an independent status as the Berks series, but it is now known that in detailed mapping they will be separated into at least two series, a mature and an immature series. The mature soils are yellow with slightly imperfect subsoil drainage somewhat like the mature Penn soils. On the large soil map (pl. 5, sec. 8) they have been combined with the Muskingum soils, a widely prevalent series in the Appalachian region. (See p. 25.)

Within the glacial region, that is, north of Delaware River, the soils of the Great Valley have been mapped mainly as members of the Dutchess series, the predominant type being a silt loam. A few small areas, mainly in the eastern part of the valley in southern New York, were mapped as members of the Dover series. The Dutchess soils, although they occur mainly in the Great Valley, are developed from shale material, since in the northern end of the Great Valley shales underlie a larger proportional area than south of New York State. Limestones underlie a relatively small part of the valley. In areas where the glacial material contains a large amount of limestone material, the soils are mapped as Dover. The Dutchess soils have an imperfectly developed podzolic profile, in most of the area the total thickness of glacial material overlying the bedrock being less than 3 feet. The surface layer is grayish but not so gray as the A horizon in similar soils farther south. The B horizon is imperfectly developed and in many places is not present. Because of the slight depth to bedrock, drainage is somewhat imperfect in some areas, though in other areas drainage is made so easy, because of the vertical position of the slaty structure in the shales and slates, that the soils are somewhat droughty. The imperfect development of the profile is due both to the shallowness of the layer of geologic soil material and to the recent date of its accumulation by glacial ice.

FIGURE 10.—Apple orchard on Hagerstown loam near Waynesboro, Augusta County, Va.

The Dutchess soils extend over some of the low hills of southwestern Vermont. The greater part of the western part of that State, however, the lowland areas especially, is occupied by the Vergennes soils, mainly clay loams, silt loams, and other heavy soils. They have developed from light-colored calcareous clays deposited in a southward extension of the Gulf of St. Lawrence immediately following the disappearance of the glacial ice from the region. Soil development has not gone very far in this material. The carbonates have been leached to a depth ranging from 2 to 3 feet, and some organic matter has been accumulated in the upper 2 or 3 inches of the soil, while granulation has developed in the surface soil in the well-drained localities. This structure seems to have resulted mainly, if not entirely, from the breakage into particles of the seemingly uniform material, because of expansion and contraction on wetting and drying. No texture profile has developed. The upper part of what would be the B horizon, if eluviation had taken place, has been weathered enough to assume a brownish color. The Vergennes soils are among the most imperfectly developed soils occurring in New England. They lie in a latitude and in a climatic environment in which Podzols develop on lighter textured material than that in the Vergennes soils, this seemingly being the main reason why the Vergennes have not developed the Podzol profile.

GLOUCESTER AND ASSOCIATED SOILS

A rather large number of soil series have been defined among the soils of southern New England, but their characteristics are relatively uniform. They have developed mainly from material derived from crystalline schists and gneisses and accumulated by glacial action. The soil profile, however, has been incompletely developed. All these soils from crystalline material differ very greatly from the soils developed from similar rocks in the piedmont plateau of Maryland and Virginia, where the material was accumulated by residual decay in place. The soils differ from typical Gray-Brown Podzolic soils in the degree of development of the normal profile. The difference in texture between the A and B horizons in the soils of southern New England is very slight. The texture of all the layers from the surface downward changes slightly (see Table 35) and in such a way as to indicate that the variations are due to differences in the original material and not to eluviation. The color profile

is somewhat better developed, however. The A horizon is predominantly brown. It lacks the yellowish shade so characteristic of the Sassafras soils, and the B horizon is deeper brown than the A horizon. In general, the soil material is coarse in texture. The chemical composition, which will be discussed later, shows that the minerals in the A and B horizons are not the products of decomposition of those in the C horizon but are essentially the same.

It is apparent that this slight difference in the several parts of the profile is owing, in part, to the relatively late geological age during which the glacial deposits were accumulated and in part to the coolness of the climate which has not favored rapid decomposition of the silicate minerals. In the southwestern part of New England, south of the latitude of New Haven, the evidence of a more complete decomposition of the silicate minerals becomes noticeable. Large areas of New England are covered on the soil map (pl. 5, sec. 1), by the Gloucester soils. In detailed soil survey work four more important series have been given independent status.

In northern New Jersey, in the region known as the highlands, which consists of the northern extension of the Blue Ridge, the soil material was also accumulated by glacial action. But the soil profile at the present time is better developed than in New England and the minerals are much better decomposed, there being an extensive development of clays or colloidal materials in the soil profile. The texture differentiation into a light-textured A and a heavier textured B horizon has not become so well developed as farther south, but in the definiteness with which the whole profile is developed, the soils lie between those with very poorly developed profiles in Massachusetts and Connecticut and those with much better developed profiles in Virginia and Maryland.

The Merrimac soils share with the Gloucester the whole area of southern New England according to the soil map. (Pl. 5, sec. 1.) It has already been stated that a number of soils other than these have been identified in the detailed soil work, especially in Massachusetts where the whole State has been surveyed. All the soils of the rolling uplands, where derived from glacial drift, are similar in their broad characteristics, and for that reason have been combined with the Gloucester for the purpose of the main soil map. The Merrimac soils differ from the Gloucester in their derivation from water-laid glacial material. They are, therefore, coarser in texture than the Gloucester taken as a whole, are underlain by sandy or gravelly deposits, and occur on smooth areas. They have developed for the most part from glacial outwash material. Very little profile development has taken place. Because of the very sandy character of the parent material and the practical absence of silt and clay, no well-developed podzolic texture profile is possible. Slight decomposition of feldspars seems to have taken place, and a small amount of organic matter has accumulated in the upper 2 or 3 inches. The true Podzol profile is faintly developed in some of these sands, and it is probable that, before the region was settled by white men, most if not all the areas had such a profile, but because of the smooth relief on which these sandy soils lie and the absence of boulders they were cleared and plowed at an early date. Thus the Podzol profile was destroyed.

MUSKINGUM AND ASSOCIATED SOILS

In the Appalachian region from the western side of the limestone belt of the Great Valley westward into central Ohio and stretching from the glacial boundary in northern Pennsylvania southward to Alabama a large proportion of the soils are shown on the soil map (pl. 5, secs. 1, 7, and 8) as Muskingum soils. Only a small part of this large region has been studied carefully enough to make an accurate differentiation and mapping of the soils possible. The region has an extremely uneven relief, and agriculture is not a highly developed industry. Considerable areas have been cleared of the original forest, which was mainly hardwood, and are now cultivated or in pasture, but the proportion of such areas is not large.

The impression of uniformity of soils throughout this region given by an inspection of the map is true in part only. In general, the uniformity is due mainly to the uniformity of the parent material, this being material accumulated in place by decomposition of sandstones and shales. Limestone material is present but underlies a small part of the total area. The soils also are dominantly young, belong to the Gray-Brown Podzolic group (fig. 11), are imperfectly developed, and are developing from materials that are very much alike throughout the area. Because of these conditions the soils are necessarily, in their general characteristics, similar.

Within this broad area there are two general physiographic regions. The eastern part of the large area consists physiographically of the Appalachian ridges, a region made up of parallel narrow mountain ridges separated by parallel lowland belts, wider than the ridges, but in few places attaining a width of more than 10 miles. The ridges are underlain mainly by indurated sandstones. The soils, being derived from material accumulated by residual decay of the sandstones, are sandy, shallow, and imperfectly developed. The parent material contains no carbonates and low percentages of alkalies and alkaline earths. The surface layer has been leached of its iron and some of its alumina to a considerable extent, but no well-defined B horizon has been developed.

Most of these mountain soils lie on steep slopes and have imperfectly developed profiles. Because of the imperfect profile, their development from sandstones, their forest cover, and the absence of sufficient data to warrant more detailed separation, they have been shown on the soil map as Muskingum soils except where the slopes are extremely steep and the areas mountainous. In such cases they have been grouped as rough stony land. Many more of the areas of these regions could have been included in rough stony land, but this would have required greater detail on the map. The shallow mountain-side soils, identified as Muskingum soils, differ in character, however, from soils in the areas which have been mapped as rough stony land. The latter areas have a soil cover, but it is even shallower than that mapped as Muskingum, and actual outcrops of bedrock are more numerous.

The soils in the lowland belts between the ridges are generally shallow also but less so and with a somewhat better developed profile than the mountain-side soils of the ridges. These lowland belts consist of dissected intermountain lowland plains lying about a thousand feet below the levels of the ridge tops. The soil profile, in smooth areas, is maturely developed. In such areas the soils are similar to the fully developed yellowish soils overlying the Triassic shales in Pennsylvania. The material is silt and clay mixed, rather heavy, and where thick it allows water to percolate slowly. The subsoil color, as elsewhere in similar material in the Gray-Brown Podzolic region is yellowish rather than rich brown or reddish brown as in the better developed soils east of the Blue Ridge, such as the Chester or Sassafras, or in the Great Valley, such as Hagerstown. On the steep slopes within the lowland belts the soils do not differ fundamentally from those on the steep slopes of the mountain ridges.

Associated with the Muskingum soils, both on the mountain slopes and in the lowland belts, are narrow belts shown on the map as Upshur soils. These are young soils developed from reddish shales. They are so young that the original parent rock color has not yet been changed to the normal soil color characteristic of the profile of the Gray-Brown Podzolic soils. The shales are somewhat calcareous and the soils being young carry some of this parent rock lime. This makes them somewhat more productive than the Muskingum soils in the same region.

The other physiographic division of the Appalachian region referred to above, consists of the Allegheny Plateau extending from the western side of the Appalachian ridges to central Ohio and into eastern Kentucky and eastern Tennessee. It is broad at the north and narrows southward. It includes all of western Pennsylvania, most of West Virginia, eastern Ohio, eastern Kentucky, and eastern Tennessee. A large part of the soils of this region from northern Pennsylvania southward and westward have been mapped also as Muskingum soils. In fundamental characteristics they do not differ essentially from the Muskingum soils in the eastern or Appalachian ridge part of the region. They are young soils developing from material accumulated by the decay of sandstones and shales. As a whole the region contains a larger proportion of shales than of sandstones, and the soils are therefore somewhat heavier in texture than those in the Appalachian ridge region, especially those of the mountain sides, but their profile development is no more perfect, taken as a whole.

LORDSTOWN AND ASSOCIATED SOILS

Within the glacial region of the extreme northern part of Pennsylvania and southern New York, the soils have developed from glacial material, but this was accumulated from sandstones and shales so that the soils do not differ very greatly from those in the unglaciated part of the Appalachian region, except so far as the smoother surface relief, produced by glaciation, has produced soil differences. The dominant soil in this region is shown on the map as the Lordstown. These soils are, to all intents and purposes, Muskingum soils. Being shallow, their profile is imperfectly developed. Associated with the Lordstown soils, however, are rather extensive areas of Volusia, Wooster, and Lackawanna soils.

FIGURE 11.—Profile of Zanesville silt loam, a fully developed Podzolic soil of the Muskingum group, showing the laminated A horizon.

The Volusia soils have developed on smooth areas and under the influence of excessive moisture. This is due to high ground water in places and to seepage in other places. The profile consists of a light-colored, almost gray, A horizon, a heavier B horizon, with an indurated layer immediately beneath the B horizon. In some places the intermediate heavier B horizon is lacking. These and related soils extend westward from southern New York and occupy a large area in northeastern Ohio. In detailed mapping, as may be seen by the inspection of detailed soil maps covering some of the counties of northeastern Ohio, these Volusia soils are broken up into a number of series differing from typical Volusia soils in comparatively minor characteristics.

The Wooster soils have developed in well-drained situations from thick deposits of glacial material derived from sandstones and shales. These soils occur not only in southern New York but also in rather important areas of northeastern Ohio. They constitute the most nearly normally developed soils within this general region. The profile is essentially identical in its general characteristics with that of the Chester profile in the piedmont region. They differ from the Chester soils in that their predominant shade is yellowish rather than reddish, in the B horizon especially. The A horizon is pale yellowish except the upper 2 inches in the virgin soils which are stained dark by organic matter. It is light in texture compared with the underlying B horizon. The B horizon is yellowish brown with a faint reddish shade, heavier in texture than the A horizon, usually structureless, though in the heavier types the material shows a tendency to break into angular particles similar to those in the B horizon of the Chester soils. The C horizon consists of glacial drift made up of sandstone and shale material. The composition of the Wooster soils is shown in Table 55.

The Dekalb soils, associated with the Lordstown, Wooster, Volusia, and Muskingum soils in the Allegheny Plateau, are Podzols and have been described as members of that group.

The Lackawanna soils are, like the Lordstown, shallow with imperfectly developed profiles. They are developing, however, from glacial material accumulated mainly from reddish shales. Their incompletely developed profiles are due in part to their relatively heavy texture but mainly to the same causes as those determining the im-

perfect Lordstown profiles. These are their occurrence on uneven relief and their development from geologically recent accumulations of the glacial material. Their imperfect development is expressed in the retention, except in a thin A horizon, of the peculiar red color of the parent rock. They are very similar to, if not essentially identical with, the Upshur soils and very similar to the Penn soils in the piedmont region of New Jersey, New York, and southward and in part of the Connecticut Valley lowland of Massachusetts and Connecticut.

ONTARIO AND ASSOCIATED SOILS

The northern end of the Allegheny Plateau runs across New York a short distance south of the Erie Canal. North of that is a lowland region corresponding physiographically to the Great Valley of the Appalachian region. It is underlain by shales and limestones, the latter underlying an important part of the total area. This is part of what may be designated as the Ontario lowland extending northward from the northern boundary of the Allegheny Plateau well into the Province of Ontario in Canada. The rocks are covered by glacial material, this having been accumulated to a considerable extent locally and containing therefore a large proportion of limestone material. Since the ice moved southward this limestone glacial drift was carried southward onto the northern end of the Allegheny Plateau. While the ice lay in this lowland belt, the valleys of the northern end of the plateau draining northward in preglacial times were filled with water, and in these waters deposits of calcareous silts and clays were laid down. Similar deposits were laid down in various places on the Ontario lowland in lakes that stood there at different levels as the ice retreated. These deposits are dominantly heavy, but light-textured deposits were laid down locally. The heavy deposits are calcareous as a rule. The largest most continuous area of such deposits lies along the northern border of the Ontario lowland stretching over most of the belt between the ridge road and the lake in Wayne, Monroe, Orleans, and Niagara Counties, N. Y. The soils from the dominant heavy calcareous deposits are mainly members of the Dunkirk series. In general they are young soils with an imperfectly developed profile. In many areas north of the ridge road, however, owing to the presence of ground water at a slight depth in winter and spring, a faintly indurated gray layer has developed at a depth of a foot or more in some places.

FIGURE 12.—Deciduous forest on Miami soils, Hancock County, Ind.

The soils derived from the calcareous glacial drift within this area have been identified as members of the Ontario series. In detailed mapping in this lowland two soils from calcareous glacial drift have been established, one, the Honeoye, from material containing a higher percentage of limestone material than that of the other, Ontario. On the soil map (pl. 5, sec. 1) both have been combined as Ontario.

The soil material contains a large amount of lime carbonate, but the soil profile has been well enough developed for the lime carbonate to have been removed to a depth of about 2 feet. In other respects the profile has not been well developed. The material is rather heavy in texture so that the development of an eluviated A horizon and an illuviated B horizon takes place slowly. The subsoil is slightly heavier than the surface soil, and it is somewhat lighter in color. The imperfectly developed B horizon is somewhat brown, especially in the upper part, but its color is dominated to a greater extent by the color of the parent material from which the soil is developing than is the case with the Wooster or with the better developed Muskingum soils. The percentage of organic matter in the cultivated soils of this region is relatively high as they have been used for growing grass to a considerable extent. They are closely related in their hereditary characteristics, or those derived from the parent rock, to the Miami soils (to be described later) occurring in Indiana, Ohio, and Michigan. The profile is much less well developed than in the latter soils, however.

A few small areas in northwestern New York are shown on the map as Wethersfield soil which is an imperfectly developed soil derived from glacially deposited red sandstone and shale material. The Wethersfield soils occur mainly in northern New Jersey and to less extent in the Connecticut Valley. In detailed mapping in New York they are identified as Lockport, differing from the Wethersfield in less perfect drainage, in derivation from rocks of different age, and in much more granular structure.

The Worth soils occupy a comparatively small area around the east end of Lake Ontario. They occur within the general area occupied by the ancient glacial lakes in which the silts, clays, and sands from which the Dunkirk soils are developing were deposited, but their parent material is glacial and stony, containing a considerable proportion of quartzite boulders and cobbles. The soils and soil material are noncalcareous, the profile imperfectly developed, the soils rather coarse in texture, and their productivity low.

The Clyde soils occupy a great many small areas in New York and larger areas in the lake region of Ohio, Indiana, Michigan, and neighboring States. These are black soils consisting essentially of material accumulated in low-lying areas where the organic matter has not been allowed to decay because of excessive moisture. Ground water has stood for a long time, probably since glacial times, practically at the surface. These soils are similar to, and are in a comparable stage of development with, the Portsmouth soils in the coastal plain region. The profile is wholly undeveloped as the material has not been leached, it contains a high percentage of organic matter and, where artificial drainage has lowered the ground water level, the soils are highly productive. They occupy situations where organic matter has accumulated and into which mineral matter has been carried both in suspension and solution.

The Chenango soils occur in small strips throughout the region, not only in association with the Ontario soils but with most of the other soils of the major group. They are normally developed soils with a profile similar to that of the Chester and have developed from water-laid material occurring mainly as river-terrace deposits. There are a large number of other terrace soils differentiated in the detailed mapping in the eastern part of the Gray-Brown Podzolic region, but the areas in which they occur are small and their differences from the Chenango soils are comparatively small except where they are poorly drained. The Elk soils, which differ from the Chenango mainly in the absence of limestone material in the gravel of the substratum, are wide-spread in the region. The well-drained members of all these terrace soils, including the Chenango, are shown on the map as Elk soils.

MEIGS AND WESTMORELAND SOILS

In the midst of the large area of Muskingum soils in the Allegheny Plateau area of Pennsylvania, Ohio, and West Virginia, is a large area of soils, the southern part of which is shown on the map as the Meigs and the northern part as the Westmoreland soils. These, like the Muskingum, are imperfectly developed soils because of their occurrence in a hilly region where the steepness of the slope does not allow the soil material to lie in place long enough for the full development of the normal profile of the region. They differ from the Muskingum soils, however, in their development from parent materials which contain lime carbonate, varying in amount from place to place, and also from material that is finer in grain than that from which most of the Muskingum soils have been derived. These soils therefore are heavier in texture and because of the shallowness of the soil, and therefore of the thin layer of material which has been leached of the readily decomposable material, free carbonates may be present within a few inches of the surface. The northern part of the belt, that part occupied by the Westmoreland soils, is one in which the underlying bedrock contains beds of limestone in addition to calcareous shales. Limestone is not usually present in the southern part of the belt but reddish shales, slightly calcareous as a rule, are interbedded with gray, usually noncalcareous shales identical in general lithologic character with the shales from which the Muskingum soils develop. The young soils from these interbedded rocks have been given independent status as the Meigs series. They are, essentially, mixed areas of Upshur and Muskingum soils. The presence of the Upshur soils gives the whole body a reddish color. In some cases the reddish color of the parent material is present at the surface of these soils, partly because of the heavy texture of the material which has not allowed the development of more than an inch or two of an A horizon, whereas in others, the material, being lighter in texture, an A horizon has developed, but in most cases it has been eroded because of the steepness of the slope.

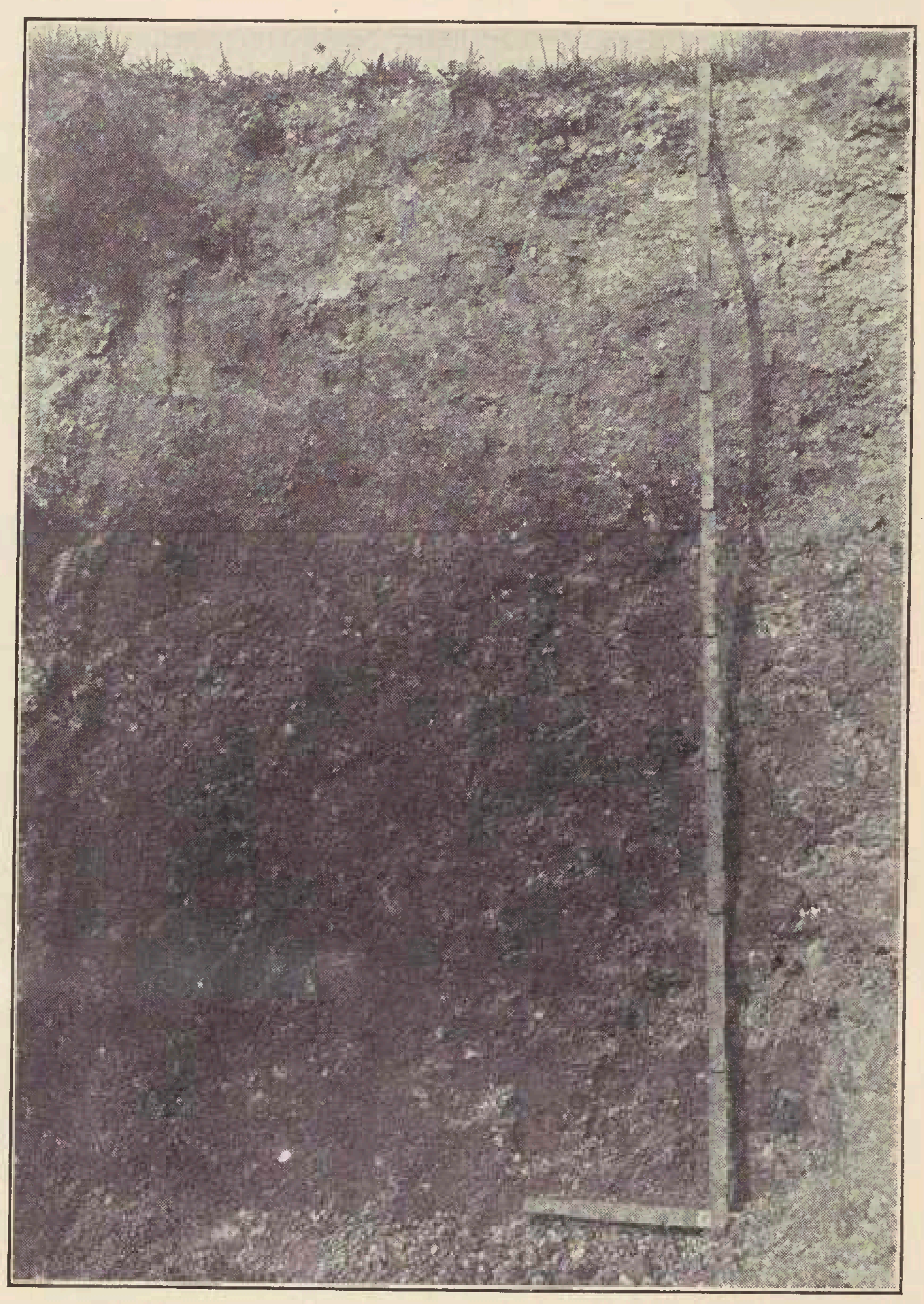


FIGURE 13.—Profile of Miami loam, East Lansing, Mich.

The area occupied by both these soils was covered in its virgin condition by a luxuriant growth of hardwood forest, the growth being more luxuriant than that on the sandy members of the Muskingum and in general more luxuriant than that on the Muskingum soils taken as a whole. They were recognized by the early settlers as productive soils, partly through the luxuriant growth of the forest vegetation, and were cleared in the early part of the nineteenth century. They are still used for agriculture, mainly for grazing. They are relatively productive soils, partly because of the imperfect development of their profile, but they can not be used for grain growing without danger of severe erosion.

MIAMI AND ASSOCIATED SOILS

A large area in western Ohio, central Indiana (fig. 12), southern Michigan (fig. 13), and southeastern Wisconsin is covered by soils of the Miami and other closely related series. This is probably the most important group of Pedalfer soils in the United States. The Miami soils, consisting mainly of the loam, the silt loam, the clay loam, and the silty clay loam members of the series, with small areas of sandy loam, are the dominant maturely developed soils. The area in which the typical characteristics of the Miami soils are best developed occupies western Ohio and central and northern Indiana. They have developed a normal profile which, because of the large area occupied by these soils, may be considered the typical Gray-Brown Podzolic profile for that part of the United States lying west of the Appalachian region. The surface soil beneath a thin layer of dark-brown leaf mold consists of dark-colored silt loam, the A_1 horizon, about 3 inches thick. This may have an imperfect granular structure. It is underlain by a light-colored, usually pale-yellowish silt loam, the

A_2 horizon, which is structureless except for a well-defined lamination in which the upper surfaces of the laminæ are lighter in color than the lower.

In the virgin soil this light-colored layer contains many insect and worm nests with dark-colored worm casts, in extreme cases the number of these being sufficient to give an apparent granulation and a dark color to the material.

The texture is light, compared with that of the underlying horizon, being predominantly silt loam. At a depth of 8 or 10 inches is the heavier rich-brown B horizon, the material of which breaks into angular particles more perfect than the particles in the corresponding horizon of the Chester soils. The surfaces of these particles have a stronger color, usually deeper brown with, in some cases, a faint reddish shade, than the insides, the latter being yellowish brown. In the lower part of this horizon, which ranges up to 18 inches in thickness, the particles into which the material breaks are larger and are coated with dark-colored material. Although this material has not been removed and analyzed separately, the composition of this horizon or subhorizon, in a few cases where the material from the whole subhorizon has been collected and analyzed, indicates that it is composed mainly of organic matter. The parent material consisting of highly calcareous glacial drift lies at a depth ranging from 18 to 40 inches. The change from the leached solum to the unleached parent material is abrupt. The solum contains no carbonates.

The Miami soils, being the normal soils of the region, have developed in normally well-drained situations. A considerable proportion of the total area, however, is not well drained, and other areas are sufficiently smooth in relief to cause imperfect though not poor drainage. On the latter areas a soil has developed having the general features of the Miami profile in the A and B horizons, but in the lower part of the B horizon a layer much heavier than that in the corresponding part of the Miami profile is present. When dry the material is very hard, but when wet it is plastic. It breaks into cubical blocks an inch or less in diameter. The outsides of the blocks are covered with an almost black coating, whereas the insides are variegated, ranging from yellow to brown. This material lies abruptly on the parent glacial material which is identical in character with that underlying the Miami soils. These soils with a heavy B horizon are mapped as members of the Crosby series. The A horizon is invariably

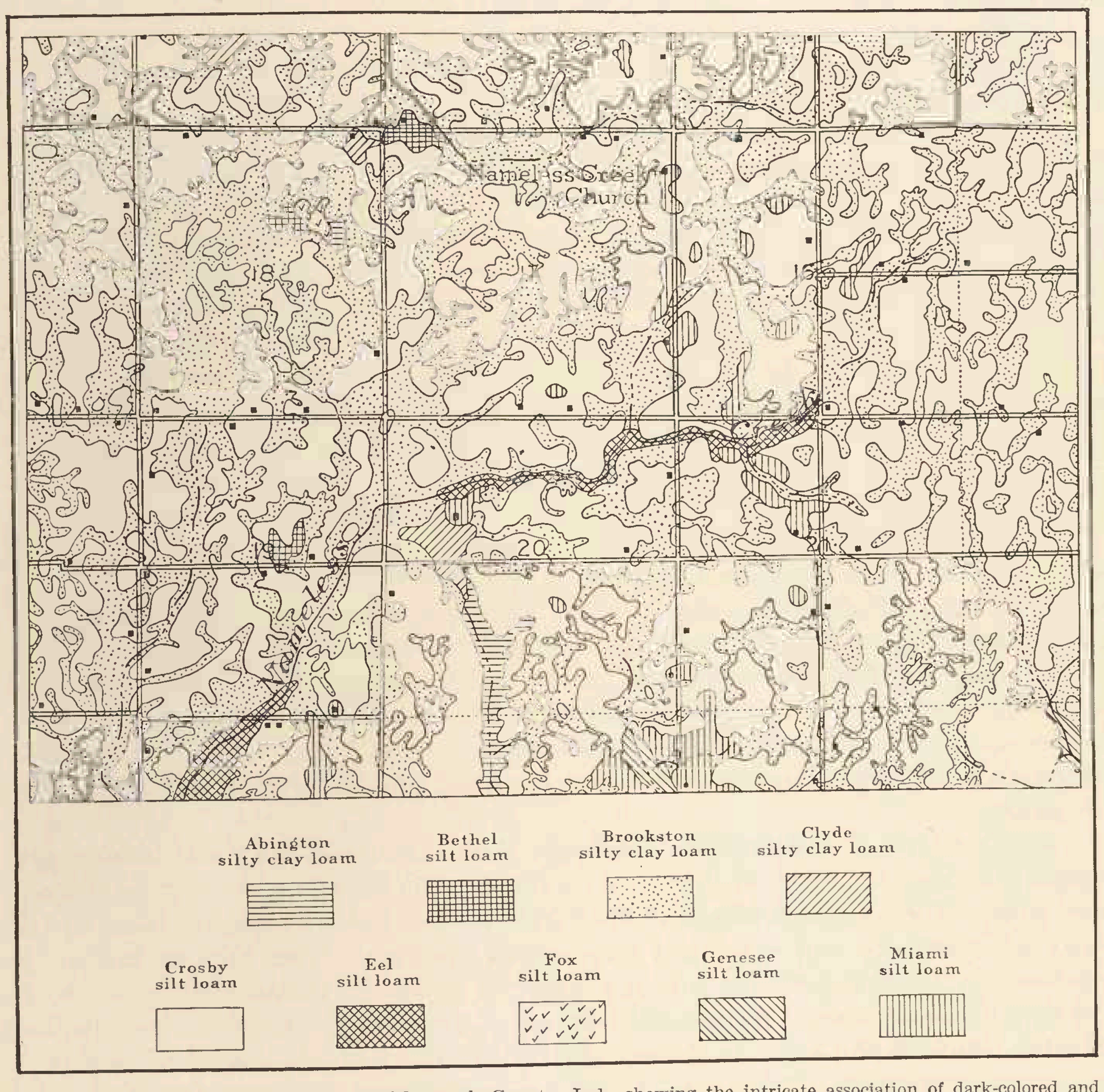


FIGURE 14.—Section of detailed soil map of Hancock County, Ind., showing the intricate association of dark-colored and light-colored soils in the region.

lighter in color than the corresponding horizon of the Miami soils showing the effect of imperfect drainage which is due in part to water logging caused by the slow percolation of meteoric waters through the heavy lower B horizon. Their occurrence on flat areas is responsible in part for the imperfect drainage of these soils.

The topographic relationship of the Miami and Crosby soils, as brought out by the detailed mapping, is essentially like that of the Sassafras and Portsmouth, or still better, that of the Sassafras and Leonardtown soils of the coastal plain of Maryland and Virginia. The Miami soils occupy rolling areas, the Crosby, flat areas. The Miami soils in central Indiana lie along the streams, the Crosby soils in the interior. In Michigan and Wisconsin, in morainic regions, the relief is predominantly rolling. The Miami or closely related well-drained soils become dominant, and Crosby soils occur in only a few places.

Although the Miami soils are the normal soils of this region, only about half of all the soils, in some cases much less than half, have developed the normal profile. It has been pointed out that the Crosby soils have an abnormally developed profile, but large areas of other soils have an imperfectly developed profile, in which there is no abnormal development but merely lack of development. This is due not only to imperfect drainage but to total lack of natural surface drainage. Such soils have been subjected to ground water, the surface of which has lain practically at the surface of the land throughout the area until within the last fifty years, since which time they have been drained by artificial means. These soils are shown on the map, where they occur in large areas, as Clyde soils. There are, however, two general groups of soils, both of which are shown on the map as Clyde, a group of black and one of dark grayish-brown soils. The black soils constitute the true Clyde soils, and the dark grayish-brown soils belong to the Brookston series. The difference between the two is a difference in the intensity of the dark color, and it is caused by difference of drainage.

The areas of Clyde soils, as shown on the soil map (Plate 5, sections 1, 2, 7, and 8), lie mainly along the Great Lakes. These constitute the large areas of soils dark enough to be grouped with the Clyde series on the large soil map, but a great number of small areas lie scattered widely over the general region of Miami and associated soils. Only the larger of these areas is shown. The small map (fig. 14), consisting of a section of the detailed soil map of Hancock County, Ind., shows the great number of these areas of dark-colored soils which are here intricately associated with the light-colored Crosby soils. The region of intricately associated Clyde, Brookston, Crosby, and Miami soils is popularly called in Indiana the "black and white" region.

In the southern peninsula of Michigan and in eastern Wisconsin, north of the general area dominated by the Miami and related soils, all of which are shown as Miami on the map, are soils which are shown as Superior. These include a number of series, all the soils of which have developed from reddish-colored calcareous glacial material. Some of this material occupies flat areas and some of it rolling morainic areas. The greater part of it is morainic, and the soils are normally well drained, but in general the texture is heavy and in this region where the climatic conditions are not so powerful in developing the normal profile of the Gray-Brown Podzolic soils as farther south, the profile is not yet well developed. Where the profile is well developed, usually in areas where the material is somewhat sandy, some of these soils are mapped, in detailed mapping, as members of the Isabella series. All these soils, however, have been shown on the soil map in this report as Superior.

Considerable areas of Fox soils are shown on the soil map in association with the Miami. These are soils with a normal Miami profile so far as the solum, or A and B horizons, is concerned, but the parent material consists of gravel deposits laid down by glacial waters flowing from the ice front, the gravels being mainly limestone. The soils have developed a normal well-defined Gray-Brown Podzolic profile. The transition from the decomposed material to the limestone gravel is fully as abrupt as that from the decomposed material beneath the Miami to the calcareous drift.

GIBSON, CLERMONT, AND ASSOCIATED SOILS

A belt of soils lies along the north side of Ohio River, extending from southwestern Ohio into southern Illinois and including several members, but soils of the Gibson series are dominant. (Fig. 15.) Typical Gibson soils do not extend throughout the whole stretch although shown as dominant on the soil map. (Pl. 5, sec. 7.) Much of the stretch has not been mapped, this being true not only in southern Indiana but also in southern Illinois. Gibson soils cover a large part of the area, but in the belt as a whole the distribution of soils as shown on the map is based on very general knowledge only. The most important or dominant soils in the belt are those of the Clermont, Gibson, and Tilsit series in Ohio and Indiana and a series designated in the old mapping of southern Illinois by the State as "gray silt loam on tight clay." It is probable that the latter soils are similar to those of the Vigo series in southwestern Indiana.

FIGURE 15.—Profile of Gibson silt loam, Mount Vernon, Jefferson County, Ill.

The soils with the simplest profile in this group are members of the Clermont series. These are soils which have developed in situations where drainage is imperfect. They lie on flat areas and have been subjected to the influence of high ground water during the winter and spring, but they dry out in summer. They were at one time covered with a forest, mainly of pin oak, with hickory in places. The flat areas on which they lie constitute remnants of the original constructional surface or of an erosional surface produced by a cycle of topographic development preceding the one now in progress.

The Clermont soils are not normal soils of the Gray-Brown Podzolic group but are mentioned first in this discussion because they may be used as a starting point. The surface soil in virgin areas contains the usual leaf mold. The upper part of the mineral soil to a thickness of 3 inches, more or less, is dark colored, due to impregnation of organic matter not highly decomposed. This is underlain by mottled material which does not change greatly in texture from the surface downward. There is no well-defined A horizon of relatively light texture and light color underlain by a B horizon of heavier texture and stronger color. There are slight variations in texture, but so far as studies have been carried, there seems to be no well-defined systematic relationship of these layers one to the other such as would be the case if they were parts of a normally developed soil profile. Percolating water has not been a strong factor in such development as has taken place. The soils have been subjected to the influence of ground water rather than to downward percolating water. The chemical composition of a profile of Clermont silt loam from southeastern Indiana will be discussed in connection with the chemical composition of the soils of the major group. The soils contain no carbonates and not a high content of alkalies and alkaline earths, although they can not be described as thoroughly leached soils. The parent material is calcareous glacial drift of Illinoian age, but the carbonate has been leached to a depth of about 10 feet from the surface.

Three series of soils, associated with the Clermont in southwestern Ohio and southeastern Indiana, include the Cincinnati, Fairmount, and Rossmoyne series. The Cincinnati soils are relatively important, but on the soil map they have been included with the Gibson soils. They occur in eroded areas and have developed, so far as development has taken place, under the influence of good drainage. They differ, however, very greatly in respective stages of development as well as in the parent materials. The Cincinnati soils lie on the slopes, especially the higher slopes, where the original calcareous Illinoian glacial drift has been uncovered and exposed They have developed from this drift and, developing under good drainage, have developed a normal Gray-Brown Podzolic profile. They represent the normal soil of the region developed from the same material as the Clermont soils. The profile in all essential features is like that of the Miami soils, but it has reached a more advanced stage of development. The A horizon is twofold, consisting of a thin dark-colored layer immediately beneath the leaf mold with a lighter colored and relatively light textured layer beneath it extending downward somewhat less than a foot. The A horizon has essentially the same structure as the corresponding horizon of the Miami soils. The B horizon is somewhat heavier than the A, has a uniform brown or faint reddish-brown color, breaks into angular particles, the color of each being stronger on the outside than on the inside, where the color is slightly yellowish brown. Between the B horizon and the unleached material below is a transitional zone of leached glacial drift. This horizon is much more consistently present in these soils than in the soils of the Miami series. It will be remembered that in the Miami soils the transition from the B horizon to the unleached parent material is in many places abrupt.

The Fairmount soils lie on steep slopes below the level of the outcrop of glacial drift. They are developing from material accumulated by the disintegration and decomposition of the underlying Paleozoic rocks consisting of limestones and calcareous shales. Only a thin layer of material has accumulated because of the steepness of the slope. Practically no profile development has taken place and very little leaching, the accumulation of some organic matter in the surface soil giving it a darkish color constituting practically the only profile development. In most cases the soils effervesce from the surface downward. The dark-colored layer is thicker and in general darker than the corresponding layer in the Cincinnati soils, the organic matter being held by the abundance of calcium carbonate in the soil material. In this respect these soils have a remote relationship to the "black waxy soils" of Texas.

The Rossmoyne soils occupy, on detailed soil maps, a fringe or border around areas of Clermont soils. They have a solum, slightly thinner than normal but otherwise typical, like that of the Cincinnati soils or the normal regional profile. Beneath this the material is essentially identical with that of the Clermont soils. The Rossmoyne soils lie in a strip which, until a very recent date (geologically) was flat and covered with Clermont soils. As the invasion of the flat Clermont area by the headwater streams of the region progresses, a narrow belt around the heads of these streams becomes relieved of ground water and normal podzolic development takes place. In a belt of small but irregular width the soil profile attains the stage described before more active erosion removes it entirely. This belt constitutes the belt of Rossmoyne soils.

In southern Illinois, the western end of this belt of soils, the topographic conditions under which the soils have developed are essentially the same as those in southwestern Ohio, where Clermont soils are dominant. The geological conditions are also seemingly identical, but no data are available regarding possible slight differences of chemical composition of soil material. The soils on the upland flats in situations corresponding to those in which the Clermont soils have developed at the other end of the belt, were developed mainly under a grass cover but they are not typical Prairie soils[12] like those in Northern Illinois, and, although they are darker in color than the Clermont soils, their topographic, geologic, and geographic relationships to the Clermont soils are so close that they are described here as related to the Clermont rather than to the Prairie soils. Their profile, however, is entirely different from that of the Clermont soils. The profile is striking, but it is not the normal podzolic profile of the region.

The surface soil is dark grayish brown and extends to a depth of 6 or 8 inches. It is thicker than the dark-colored layer of the Clermont soils but is not so dark as the thin surface layer or leaf mold. The thicker layer of dark material is due to development under grass cover. Beneath the dark-colored layer the material is gray or nearly white, structureless, but with a laminated arrangement. The gray layer extends to a depth ranging from about 12 inches to 2 feet from the surface. It is underlain abruptly by heavy tough plastic clay which varies in color from nearly black through reddish to bluish gray. The color of this layer is, however, the color of the outsides of the particles into which the material breaks on drying. Owing, presumably, to the expansion and contraction on wetting and drying, this material breaks into more or less cubical blocks, varying greatly in size. The primary blocks range around an inch in diameter, but these break further into very small but angular particles. This layer ranges up to a foot or a little more in thickness and is underlain by heavy mottled clay which in turn is underlain by the unweathered calcareous Illinoian drift lying at a depth of 10 feet, more or less. This soil is shown on the map as Cory, but considerable areas in Illinois, south of the area of Cory soils, shown on the map as occupied by Gibson soils, are occupied by Cory soils. In the mapping by the Illinois Soil Survey the soils of this part of the State have been differentiated into a number of types, but the basis of differentiation is not exactly the same as that used here. An attempt is made here to generalize and express the soils in terms of the features to which weight is given by the Bureau of Chemistry and Soils. The results, as shown on Plate 5, section 7, of the soil map, must be regarded as very general.

The Cory soils lie on flat uneroded areas. Along the stream belts or the narrow hilly belts along the creeks in southern Illinois, soils with a profile in the upper part of the solum identical in general character with the normal podzolic profile—the Miami or Cincinnati profile—have developed, and similar soils lie south of the main Cory areas, occupying most of the southern part of the State. These soils are indicated on the soil map (pl. 5, sec. 7) as members of the Gibson series. Their characteristics are intermediate between those of soils like the Miami or Cincinnati and those of the true Gibson. In the extreme southern end of the State the soils have developed from loess. The profile resembles Miami, but on account of their southern situation assume to some extent the features of the Memphis soils (p. 44). They have been combined for the purpose of the soil map in this ATLAS with the Clinton soils (p. 30).

[12] They are included with the Prairie soils on the legend of the soil map. (Pl. 2.)

The Gibson series includes soils developed, under conditions of good drainage and also under forest cover, not merely from the same material as that from which the Cory soils are derived, but also soils which have developed in part from original Cory soils. A normal soil developing from the parent material from which the Cory soils have developed would have the Cincinnati profile, but the Gibson profile is not identical with that of the Cincinnati because of the presence of what seems to be an inherited remnant of the heavy layer present in the Cory soils.

The profile of the Gibson soils in its upper part is essentially identical with the corresponding part of the profile of the Cincinnati soils. In the lower part of the B horizon, however, gray spots begin to appear and these increase in number downward until, at a depth ranging from 2 to 3 feet, they have become so large a part of the whole soil mass as to form a more or less well-defined gray layer. This varies in definiteness of expression from place to place, depending on the perfection of drainage. The gray layer is immediately underlain by heavy rather tough plastic clay which breaks definitely into well-defined vertical columns. The upper ends of the columns terminate abruptly and are rounded. They grade with depth into the weathered leached material identical with that under the Cory soils. Presumably the situations in which the Gibson soils now lie were formerly occupied, before the present erosion cycle developed, by soils similar to those of the Cory series or former representatives of these soils. As the topographic cycle within the region ran its course, lowering the ground-water surface and allowing the normal soil profile to develop, the Gibson soils, formed on flat areas and, being presumably similar in character to the Cory, have developed a normal profile in the upper part but retain a remnant of the original heavy layer in the lower part of the soil profile.

In southern Indiana and northern Kentucky a considerable area of Tilsit soils is shown on the map. These are soils which have developed from material accumulated by the decomposition of sandstones and shales in place on flat relief in situations topographically similar to those occupied by the Clermont and Cory soils but with better surface drainage. They have developed under timber cover, and the upper part of the profile is essentially identical with the normal profile of the region, with the exception of a slightly more yellowish color in the B horizon than occurs in the Cincinnati or Miami soils. Beneath the B horizon, however, these soils are similar to the Gibson soils. In the lower part of the B horizon gray spots begin to appear. These increase in number with depth and finally develop into a more or less well-developed gray layer which is, in turn, underlain by a heavier layer.

The area of sandstones and shales in southern Indiana, on the flat areas on which the Tilsit soils have developed, extends southward and occupies a large area in Kentucky. The larger part of this area, as well as a fringe around it in Indiana is covered on the soil map (pl. 5, sec. 7) by Muskingum soils. Small areas, however, of Tilsit soils occur well distributed over this area. These Tilsit soils in Kentucky have developed from sandstone and shale material accumulated in place through the decay of those rocks. The profile seems to be slightly different from that of the Tilsit soils in Indiana. In the Kentucky area the layer corresponding to the heavy clay with columnar breakage underlying the gray layer in the Indiana soils seems to be lighter in texture than clay and is an indurated layer rather than a tough plastic and columnar layer. This is known to be the case in parts of the area, especially in Muhlenberg County, but the rest of the area has not been studied.

Associated with the dominant and most characteristic soils of this region, which have just been described, are a number of less important soils. One of the series consists of the Muskingum soils, already described, which lie east of the area of Tilsit soils in Indiana and surrounding the Tilsit area in Kentucky. The Muskingum soils, fringing the Tilsit areas in both Indiana and Kentucky, are essentially identical in both States. These soils occur on slopes, and because of such occurrence have not developed the normal mature profile of the region. The A and B horizons have not been clearly developed by eluviation and leaching, and in considerable areas they are shallow.

Another area of Muskingum soils, larger than that along the Tilsit border belt, is separated from the latter in Indiana by a belt of soils shown on the map as Hagerstown soils. The latter are soils developed from material accumulated in place by the decay of limestones and developed under good drainage. This area in Indiana is separated in detailed mapping into a number of series, all from limestone material and each characterized by the general features of the Gray-Brown Podzolic soils, but differing one from the other in minor details of profile features caused by imperfect but not poor drainage, shallowness of parent material layer, incipient development of Gibson features in the deep subsoil, and other minor features. They have all been grouped and shown as Hagerstown on the soil map. (Pl. 5, sec. 7.) (For Hagerstown description see p. 24.)

This belt extends into Kentucky from Indiana, stretching along the east and south sides of the Tilsit-Muskingum area in the latter State. Along the east side of this area the belt contains soils like those in Indiana. That part along the south side is made up of soils in which the B horizon is distinctly reddish rather than brown or faintly reddish brown. The A horizon is yellowish below the upper 3-inch layer which is dark colored. These soils, on the basis of the color of the B horizon, could be grouped with the Red and Yellow soils. They have developed from limestones containing a high percentage of carbonates and a low percentage of siliceous impurities, except chert lenses. Such rocks in the eastern United States are always covered by soils redder than the normal mature soils, derived from other rocks, associated with them.

The Lowell soils occupy a large area in northern Kentucky west of the broad area of Muskingum soils lying in the Allegheny plateau of the eastern part of the State. The Lowell soils as shown on the map cover a large area, indicated as uniform throughout, but the uniformity is apparent only and is due to an absence of information. The existing knowledge regarding the characteristics of the soils of this area is practically nil so far as definite knowledge of specific soil character is concerned. The same statement can be made regarding the character of the soils in practically any other part of Kentucky. The only basis for such differentiations as have been made in the State is that gained in the study of three or four small areas, supplemented by general geographic and geologic knowledge.

The soils within the area marked Lowell on the map have developed from material accumulated by the decay of limestones in place, the limestones being relatively low in carbonates and high in argillaceous impurities but generally free of chert. The soils are light colored in the A horizon and have a faint reddish-brown or brown B horizon which in many places is thin or entirely absent because of shallowness of the

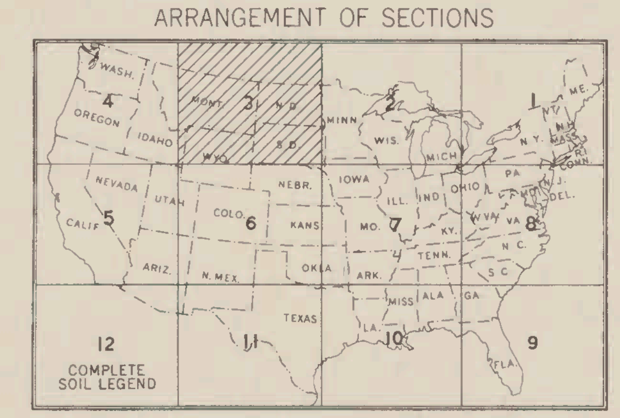
LEGEND FOR THIS SECTION

Aiken (Ai)	Everett (Ev)	Moscow (Mw)	Scobey (Sco)
Barnes (Bs)	Fargo (Fa)	Otero (Ot)	Scott (Sn)
sandy type	Fortine	Pierre (Pi)	Stockton
Bearden (Be)	Grantsdale (Gt)	Phillips	Trenton
sandy type	Hyrum	Portneuf	Williams (Ws)
Bridger (Br)	Joplin	Ritzville (Rz)	sandy type
Daniels (Dn)	Jordan	Rosebud (Ro)	Bad land (Bad)
gravelly type	Laurel	sandy type	Marsh and Swamp
Dawes	Lewistown	gravelly type	Rough and Stony land (Rsn)
Deschutes	Meeker	Sioux	Sand (S) light
	Valentine (Va)	Wabash (Wh)	

Landscape of Dark-Brown soils (Scobey) near Dooley, Sheridan County, Mont.

Grain elevators at West Hope, Bottineau County, N. Dak.

ARRANGEMENT OF SECTIONS



Lith. A. Hoen & Co., Inc.

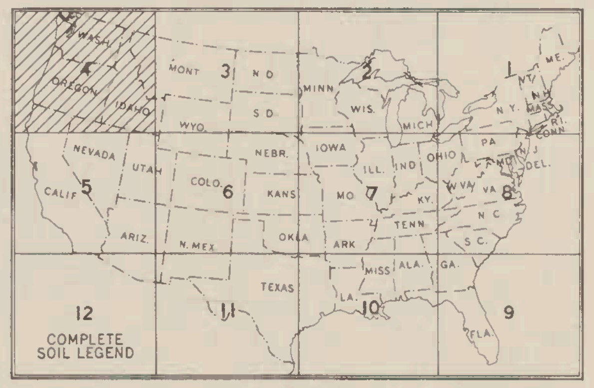
LEGEND FOR THIS SECTION

Aiken (A)	Grantsdale (Gt)	Portneuf (Pf)	Summit (Sm)
Altamont (Alt)	Helmer (Hr)	Quincy (Qy)	Toutle (To)
Bridger (Br)	Humboldt (Hd)	Ritzville (Rz)	Trenton (Tn)
Colville (Ce)	Hyrum (Hy)	Sacramento (Sr)	Yolo (Y)
Daniels (Dn)	Jordan (Jn)	San Joaquin (Sj)	Willamette (Wl)
Deschutes (Des)	Lahonton (Lh)	Scobey (Scb)	Williams (Ws)
Ephrata (Ep)	Melbourne (Mel)	Sierra (Se)	Willows (Wt)
Encina (Ee)	McCammon (McC)	Snake (Sk)	Marsh and Swamp (Ms)
Everett (E)	Moscow (Mw)	Spanaway (Sp)	Peat and Muck (M)
Fortine (Ftr)	Onyx (Ox)	Springdale (Sa)	Rough and Stony land (Rs)
Fresno (Fr)	Palouse (Pa)	Stockton (St)	Sand (S)
Amity (Ay)			light Bad land (Bad)

"Brakes" on open spaces in the forests of the Northwest, Chehalis County, Wash.

Barley on soils of the Willamette Valley, Linn County, Oreg.

ARRANGEMENT OF SECTIONS



Lith. A. Hoen & Co., Inc.

soil. In such cases these soils approach the Fairmount soils in character. Where the layer of disintegrated and decomposed material overlying the limestone rock is 4 feet or more thick and drainage good, a profile similar to that of the Hagerstown soils is developed, but the layer of disintegrated material beneath the B horizon is tough, sticky, and plastic rather than friable as in the case of the Hagerstown. The lower part of the B horizon in many places contains dark-colored splotches of iron or manganese oxide, indicating imperfect drainage. One or two analyses of samples from these soils have been made and will be discussed later.

The Clarksville soils, as shown on the map, occupy a narrow belt along the west side of the Lowell area in Kentucky and a broader belt extending southward from the south side of the same area, over a belt lying west of the large Allegheny-Muskingum area of Kentucky and Tennessee. The Clarksville belt in Tennessee is narrow. These soils occupy long narrow strips in the intermountain valleys of the Appalachian region of Tennessee, Georgia, and Alabama, and a larger area is in the Ozark region.

FIGURE 16.—Strawberries on Baxter stony loam, Newton County, Mo.

Very little definite knowledge regarding the characteristics of the soils in all these areas is available, as practically no studies have been made of them. Such knowledge as is available is based on information obtained at random in traveling back and forth over the country while carrying on field research in other areas. No more work has been done by modern methods in Tennessee than in Kentucky and but little more in the Clarksville region of Missouri.

In general the Clarksville soils have developed from material accumulated by the decay in place of cherty limestones. The amount of chert in the soil material and the soil is usually large, in many cases amounting to 75 per cent. The presence of this large amount of chert has favored leaching. The soils have developed under a high rainfall, a relatively warm temperate climate, and an oak forest cover which is often scrubby. The surface soil is light in color, in many places gray at the surface, but it changes to pale yellow at a depth of a few inches. The B horizon is yellow with a faint reddish shade, and the disintegrated parent material below the B horizon is red. It is apparent that the color of the A and B horizons is due to excessive leaching,

FIGURE 17.—Typical hardwood (red oak) on Baxter stony loam, Newton County, Mo.

the iron being partly removed even from the latter. It can not be ascribed to imperfect drainage since drainage is good throughout.

These soils constitute essentially a projection of the Red and Yellow Soils northward into the general region of Gray-Brown Podzolic soils. They are like the Red and Yellow soils in many profile features and in the thoroughness with which they have been leached.

BAXTER AND ASSOCIATED SOILS

In that part of the Ozark region underlain by limestones, covering southern Missouri and a small part of northern Arkansas, the dominant soils are members of the Baxter series. (Figs. 16 and 17.) These are reddish members of the Gray-Brown Podzolic soils. Their red color is in part a result of their development along the southern border of the region. Throughout this part of the belt, extending from the mouth of Chesapeake Bay westward along the southern border of the Gray-Brown Podzolic region the soils are reddish.

Baxter soils have been mapped in the western part of the central Tennessee limestone region in association with the Hagerstown soils. The profile consists of a light grayish-yellow A horizon, with a thin dark-colored layer at the surface, and a reddish-brown B horizon with a relatively slight development of the texture profile. (Fig. 18.) This is caused in part by the great abundance of chert fragments in the soil material, which has allowed oxidation but has not favored eluviation. It is possible, however, that the absence of extensive eluviation is partly owing to the prevailing occurrence of these soils on comparatively steep slopes. The soils are relatively young, the material not having been allowed to lie in place long enough for profile development other than the color profile. Their reaction is definitely acid, and the iron has been removed from the A horizon. They may be considered as reddish members of the Clarksville series, but because of their occurrence on smooth relief, their less well developed profile, and their less leached condition, they are somewhat more productive than the Clarksville soils which occur on smoother areas than the Baxter soils.

On flat areas in the Ozark region as well as in the highland rim of Tennessee, a soil has developed from the same material as that from which, in better drained or more rolling areas, Clarksville or, on the steeper slopes, Baxter soils have developed. (Figs. 19 and 20.) This soil has a pale grayish-yellow A horizon and a yellowish-brown B horizon with a slight reddish shade, becoming mottled with gray spots in the lower part, and finally grading into an indurated horizon at a depth ranging from 24 to 40 inches. This profile is essentially identical with that of the Leonardtown soils in the coastal plain of Maryland, and the Rittman soils in northern Ohio. They are shown on the soil map, Plate 5, section 7, as Lebanon soils. In the highland rim of Tennessee these soils are shown mainly as members of the Clarksville series because of the small areas in which they occur. They lie, however, along both the east and west sides of the general region in Tennessee in which the Hagerstown and Baxter soils occur. They are identified in detailed work as members of the Lebanon series.

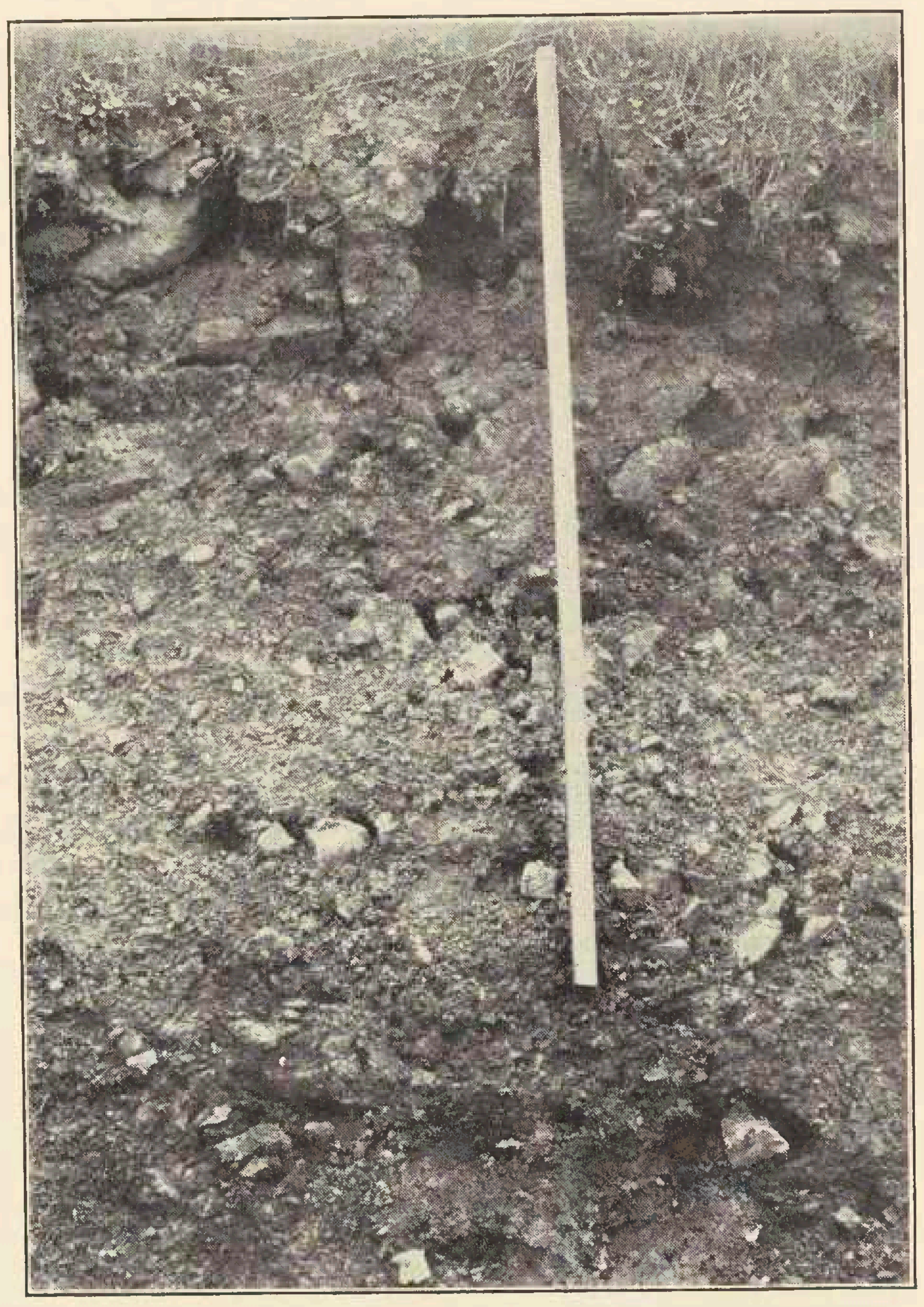


FIGURE 18.—Profile of Baxter stony loam, Newton County, Mo.

In the southwestern part of the Ozark region, small areas mapped as Crawford consist of soils practically identical in their general characteristics with the reddish phase of the Hagerstown soils in northwestern Alabama and extreme southern Tennessee. They have developed from limestones containing a small amount of chert and have not been leached sufficiently to have produced the yellow color in the surface soil, which is associated with the Clarksville or Lebanon soils.

GRAY-BROWN PODZOLIC SOILS IN PRAIRIE REGION

Along the streams in the prairie region of Missouri, Illinois, Iowa, and neighboring States, where the relief has been made rolling or somewhat hilly during the development of the existing topographic cycle, light-colored soils belonging to the Gray-Brown Podzolic group have developed. These areas, before their dissection, constituted part of the smooth plain, remnants of which now lie on the broad watersheds between the streams and on which prairie soils have developed. Before the dissection, these areas may have been covered with Prairie soils. If so the erosion involved in the dissection removed the latter. The undeveloped soils on the newly exposed material were not so favorable to the growth of a luxuriant cover of grass as the smooth uneroded plains between the valleys. Forest trees established themselves, presumably because of the lack of competition with grass. Soil development, under the humid climate of the region and a forest cover, necessarily produced soils belonging to the Gray-Brown Podzolic group. As will be explained under the discussion of the Prairie soils, the only reason, so far as is now known, why the latter have not developed the characteristics of the Gray-Brown Podzolic soils is the influence of the grass cover. Where the grass vegetation was not luxuriant enough to prevent forest invasion, the conditions controlling soil development were identical with those in the Miami region farther east. These soils consist mainly of members of the Clinton and Lindley series.

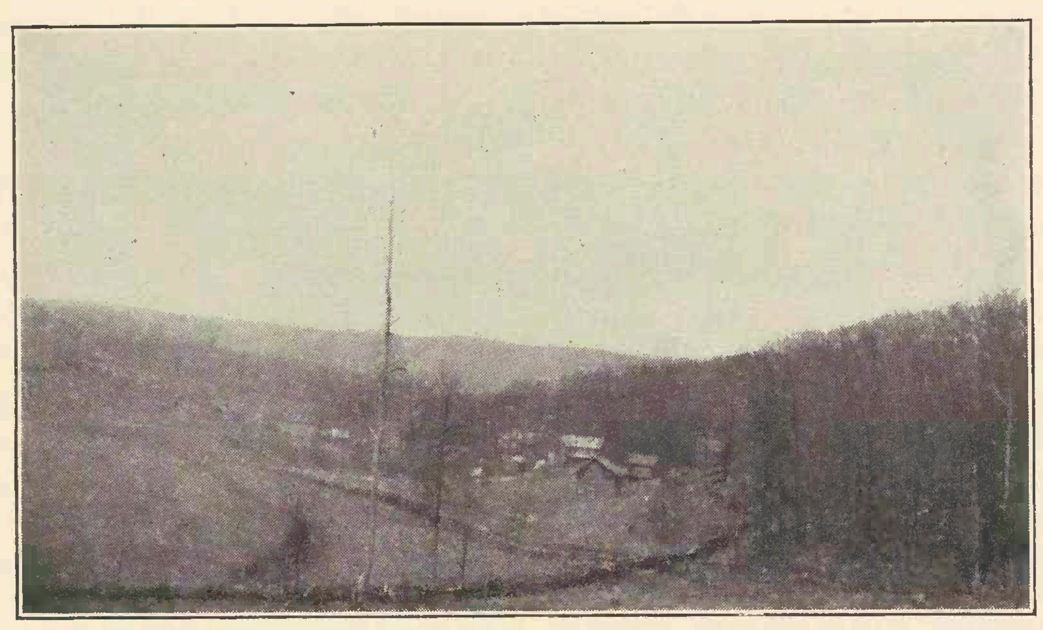


FIGURE 19.—Landscape of Baxter gravelly loam, Dickson County, Tenn. Hardwood forest on right.

An important belt of Gray-Brown Podzolic soils, mapped as members of the Clinton series, lies along both sides of the Mississippi River from the mouth of the Ohio northward to Minnesota. This belt varies greatly in width, being narrow in Illinois and southeastern Iowa but very much broader in the driftless area of northeastern Iowa and adjacent parts of Minnesota. These soils have developed from silty material which, presumably, is loess. If loess, it is relatively old and, except where the slopes are steep, a normal soil profile has developed on it. This is a typical Miami profile. The soils are not identified as members of the Miami series, however, because of their probable derivation from loess, even though it be calcareous. In all essential characteristics of the solum, however, the Clinton soils are Miami soils. The A horizon is well developed. It is grayish brown in color with a thin layer impregnated with organic matter at the surface beneath a thin layer of leaf mold, and the B horizon is brown with a faint reddish shade, especially in the southern part of the belt. The material breaks into the usual small angular particles similar to those in the B horizon of the Miami. The lower part of the B horizon of the Clinton soils differs from the corresponding part of the Miami in the absence of the thin dark-colored coating on the outsides of the breakage particles. So far as the solum is concerned this is practically the only difference from the Miami. The outsides of the structure particles are stronger in color than the insides, the latter being slightly yellowish. The B horizon is underlain by rather loose silty material from which the lime carbonate has been removed in the upper part but is still present within a few feet below the B horizon, usually less than 10 feet from the surface. Where the layer of silty material is less than 10 feet thick the lime carbonate has in places been entirely removed.

The Boone soils in western Wisconsin have a typical Gray-Brown Podzolic profile, very similar to that of the Clinton soils. These soils have developed from material accumulated by the disintegration of sandstones and shales.

In northeastern Missouri and adjacent parts of southeastern Iowa and in smaller areas elsewhere, soils of another group, with a general profile essentially identical with that of the Clinton soils but which have developed from glacial drift, have been given independent status as members of the Lindley series. They occupy narrow belts along the streams in the prairie region of those parts of Iowa and Missouri just mentioned. Several other soil series have been mapped in this region, but they do not differ, so far as general characteristics are concerned, from the Clinton and Lindley soils and have all been placed on the map as members of these series.

FIGURE 20.—Lumbering scene on Baxter stony loam, Dickson County, Tenn.

Broad belts of alluvial material lie along all the streams in this region, the width varying mainly with the size of the stream. The material from which this alluvium came is mainly Prairie-soil material. It is relatively dark, especially the alluvium along the Mississippi River and along the streams in the prairie region. These dark-colored soils have been mapped mainly as members of the Wabash series. East of the prairies, however, light-colored alluvial soils lie along the streams. They are shown on the map as members of the Waverly, Genesee, and Huntington series. The Waverly soils are usually silty, almost white in color, in many places underlain by heavy tough clay subsoils, and are poorly drained.

The Huntington soils are brown well-drained alluvial soils deposited along streams south of the glacial boundary, which flow across country underlain by rocks containing an important limestone constituent. The Genesee soils are also brown well-drained soils occurring mainly along streams draining glaciated regions. The Genesee and Huntington soils are similar in their general characteristics.

The Gray-Brown Podzolic soils cover a large area in the United States. They were settled at an early date, are moderately productive, and occupy a region in which the climatic conditions are favorable to agricultural development. Yields are not high, but under careful treatment they are good, the variety of crops that may be grown is very great, and the situation with respect to markets is favorable.

COMPOSITION OF GRAY-BROWN PODZOLIC SOILS

Samples from the most important series groups of the Gray-Brown Podzolic soils have been subjected to complete chemical analyses. The samples were collected very carefully, by horizons, and practically all of them from virgin soil. In all cases complete fusion analyses were made, and in a few the colloid material was extracted and subjected to complete analysis. In most cases the parent material, presumably identical with the unconsolidated material now lying beneath the solum, has been included, but in none has the consolidated rock been sampled along with the sampling of the soils.

The Gray-Brown Podzolic soils have developed from materials ranging widely in geologic age, character, and mineralogical composition including Paleozoic, Archaean, and Triassic consolidated rocks, sandstones, shales, limestones, schists, gneisses, and eruptives; unconsolidated sands, clays, and marls of Cenozoic age and deposits of Pleistocene age including ice-laid, wind-laid, and water-laid materials. In a few cases, such as the Chester, Penn, and Hagerstown soils, the composition of rocks that can be identified with reasonable certainty as the sources of the parent soil materials, has been published in geological literature. In by far the majority of cases, the soils of the Gray-Brown Podzolic group have developed from unconsolidated rocks, and these constitute the C horizon in the tables of analyses.

COMPOSITION OF SASSAFRAS SOILS

The tables of analyses covering the Gray-Brown Podzolic soils (tables 14, 16, 18, and 19) include four samples, from as many different localities, of Sassafras soils. The sample from Cabin Creek, Dorchester County, Md., was collected from a locality where the profile features of the series were well developed. It includes the leaf mold, a thin A_1 horizon with nearly 4 per cent of loss on ignition, practically all of which represents organic matter mixed with the sand, a thick sandy A_2 horizon, a well-defined B horizon, and a loose reddish-yellow sandy C horizon below a depth of 33 inches. The mechanical analyses (table 14) show a total silt and clay content in the B horizon of 22.3 per cent, in the C horizon of 16.5 per cent, and in the A_2 horizon of 7.8 per cent. The texture profile is well developed. The high content of silt and clay, indicated in the mechanical analyses, in the leaf mold consists merely of finely divided organic matter.

TABLE 14.—*Composition of Sassafras sandy loam, Cabin Creek, Md.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29406	A_0		a 59.46	0.28	1.48	3.15	0.01	0.45	0.25	1.20	0.16	0.11	0.22	32.60	99.37	0.770	------
		--------	b 88.22	.42	2.20	4.69	.01	.67	.37	1.78	.24	.16	.33	-------	99.38	-------	------
29407	A_1	0- 2½	a 87.83	.34	1.76	3.92	.01	.24	.14	1.62	.16	.03	.06	3.87	99.97	.080	------
			b 91.38	.35	1.83	4.08	.01	.25	.15	1.69	.17	.03	.06	-------	100.00	-------	------
29408	A_2	4–20	a 90.57	.29	1.11	4.77	.01	.16	.14	1.62	.09	.02	.05	1.45	100.27	.020	------
			b 91.90	.29	1.13	4.84	.01	.16	.14	1.64	.09	.02	.05	-------	100.27	-------	------
29409	B	20–32	a 80.74	.34	2.25	10.58	.01	.74	.26	1.97	.44	.08	.06	3.67	101.14	.022	------
			b 83.83	.35	2.34	10.98	.01	.77	.27	2.04	.46	.08	.06	-------	101.13	-------	------
29410	C	33–60	a 82.03	.29	2.25	8.57	.01	.76	.20	2.07	.42	.07	.07	3.01	99.74	.006	------
			b 84.60	.30	2.32	8.83	.01	.78	.21	2.13	.43	.07	.07	-------	99.76	-------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29406	A_0	--------	7.2	31.0	9.2	12.8	1.1	18.7	19.9	99.9
29407	A_1	0- 2½	10.5	36.4	15.3	20.9	1.9	9.1	5.8	99.9
29408	A_2	4–20	18.2	46.8	13.4	13.4	.4	4.8	3.0	100.0
29409	B	20–32	2.2	16.6	14.3	41.6	3.0	10.1	12.2	100.0
29410	C	33–60	4.9	30.2	19.6	26.0	2.6	7.0	9.5	99.8

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough, S. Mattson, G. Edgington, and I. A. Denison.
[3] Analyzed by A. A. White.

The chemical composition, Table 14, shows the highest content of silica, 92 per cent, in the A_2 horizon and the lowest in the B horizon. The content of alumina is highest, 11 per cent, in the B horizon and lowest in the A_0 horizon, though all the subhorizons of the A horizon are much alike. The C horizon contains nearly 9 per cent alumina. The content of iron oxide is lowest in A_2, as would be expected, and highest in B, though those in B and C are practically identical. The percentages in A_0 and A_1 are not widely different but are much higher than in A_2.

The complete analysis does not indicate any concentration of alkalies and alkaline earths in the B horizon, but the percentage of CaO is nearly twice as high in the leaf mold as in the rest of the A horizon but less than in B or C. The percentage is small in all cases and the proportion of possible analytical error is necessarily large. The higher percentage in A_0, however, is consistent with the results obtained in the Gray-Brown Podzolic soils in general.

The complete analysis shows an apparent accumulation of alumina in the B horizon over that in the C and a marked loss of the same constituent in all divisions of the A. It shows also that there is no accumulation of organic matter in the B horizon, differing from the Podzols in this respect, the amount in A_0 being a little less than 30.

The amount of feldspathic material in the coastal-plain deposits is extremely small. Any accumulation of alumina in the B horizon over that in the C can be due, to an extremely slight extent only, to the more thorough decomposition of the feldspars and the consequent loss of silica.

The several ratios, sa, sf, and ba, as well as the molecular equivalent composition in SiO_2 Al_2O_3, and Fe_2O_3 are shown in Table 15.

TABLE 15.—*Sassafras sandy loam, Cabin Creek, Md.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
29408	A_2	4–20	32.3	215.4	0.454	1.53	0.007	0.047
29409	B	20–32	12.99	94.9	.398	1.39	.014	.107
29410	C	33–60	16.28	96.6	.502	1.409	.014	.086

The silica-iron oxide ratio in B and C are the same. The alumina in B, however, has been increased by 25 per cent. Both iron oxide and alumina in A_2 have decreased, but the iron oxide has been lost from the solum, whereas at least part of the alumina has been precipitated in B. The lack of precipitation of iron oxide in B may possibly be due to the low content of bases.

The sa ratios for the B and C horizons of 13 and 16.28 show an increase of about 20 per cent of alumina in the B horizon, practically all of which must be due to illuviation. The much larger figure for the A horizon shows a very great loss of alumina, apparently more than can be accounted for by the accumulation in the B horizon. The ratios of silica to iron oxide in the B and C horizons are nearly the same, that for the B horizon showing an accumulation of little more than 1 per cent. The B horizon in this soil is one in which alumina alone has accumulated to an important extent.

The ba figures show important loss of alkalies and alkaline earths in both the A_2 and B horizons. When, however, allowance is made in the B horizon for the accumulated alumina, about 20 per cent over that in the C, it will be seen that the difference between B and C becomes very small.

The sample from Atlantic, Va. (Table 16) has a well-defined color and texture profile. The mechanical analysis shows the percentage of clay in the A, B, and C horizons to be 6.8, 29.8, and 6.6 per cent, respectively. The complete analysis shows an apparent accumulation of alumina in the B horizon and of silica in the A.

TABLE 16.—*Composition of Sassafras sandy loam, Atlantic, Va.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29419	A	1½–10	[a]85. 96	0. 59	1. 74	6. 26	0. 04	0. 40	0. 36	1. 54	0. 58	0. 02	0. 07	1. 91	99. 46	0. 020	------
			[b]87. 61	. 60	1. 77	6. 38	. 04	. 41	. 37	1. 57	. 59	. 02	. 07	------	99. 43	------	------
29420	B	13 –34	[a]81. 05	. 59	3. 21	9. 13	. 03	. 20	. 40	1. 65	. 49	. 02	. 05	2. 80	99. 62	. 020	------
			[b]83. 38	. 61	3. 30	9. 39	. 03	. 21	. 41	1. 70	. 50	. 02	. 05	------	99. 60	------	------
29421	C	34 –53	[a]87. 38	. 41	1. 26	6. 32	. 01	. 46	. 18	1. 75	. 76	. 01	. 05	1. 15	99. 74	. 010	------
			[b]88. 39	. 41	1. 27	6. 39	. 01	. 46	. 18	1. 76	. 77	. 01	. 05	------	99. 70	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05–mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29419	A	1½–10	0. 4	2. 2	3. 7	49. 4	6. 0	31. 4	6. 8	99. 9
29420	B	13 –34	0. 0	1. 2	2. 4	48. 0	4. 9	13. 5	29. 8	99. 8
29421	C	34 –53	0. 0	1. 3	2. 9	75. 2	7. 4	6. 7	6. 6	100. 1

[1] Collected by C. F. Marbut.
[2] Analyzed by R. S. Holmes, S. Mattson, G. Edington, and I. A. Denison.
[3] Analyzed by A. A. White.

The amount of feldspathic material in the C horizon, according to rapid microscopic examination by W. H. Fry, of the Bureau of Chemistry and Soils, is no greater than in the Dorchester County, Md., sample. The possibility that the ratios have been influenced by the decomposition of silicates (feldspar) and the loss of silica may be left out of consideration.

The several ratios, sa, sf, and ba, as well as the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 17.

TABLE 17.—*Sassafras sandy loam, Atlantic, Va.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
29419	A	1½–10	23. 3	131. 17	0. 536	1. 45	0. 011	0. 062
29420	B	13 –34	15. 0	67. 0	. 324	1. 33	. 02	. 092
29421	C	34 –53	23. 5	184. 43	. 628	1. 46	. 0079	. 062

The sa ratios for B and C are wider apart than in the Dorchester County, Md., soil, that for B being 40 per cent smaller than for C, whereas those for A and C are identical. This fact is shown also by the total quantities. The A horizon has a relatively high content of alumina, however, the content of fine material being high. The high percentage of silica in A is the result of eluviation, that in C is owing to the character of the parent material. It is clear that alumina has taken part, to an important extent, in the eluviation, while the nitrogen content of the three horizons shows lack of accumulation of organic matter in B.

The sf ratios show also an important accumulation of iron oxide in the B horizon. On the basis of these results, those of the complete analysis, the molecular equivalent composition and the profile characteristics of this soil, its designation as a Podzolic soil in which both iron oxide and alumina have been shifted from A to B is justifiable. The ba ratios show an important loss of alkalies and alkaline earths in the B horizon and a smaller loss in A.

The sa ratios are high in all the Sassafras soils. This is necessarily so because of their sandy texture and therefore the high percentage of free silica present. The percentage of quartz has not been determined in any of the samples. The procedures adopted by European chemists for determining this by acid digestion (*8*) have not been widely adopted in this country. The extraction and analysis of the colloidal material is being used rather widely, however (*14*). The sa ratios in this material, on the assumption that it contains practically no free quartz or other undecomposed minerals, should show the degree of kaolinitic or lateritic decomposition that has taken place.

A sample of Sassafras silt loam from Talbot County, Md., was analyzed by Robinson and Holmes (*15*) the results, including the composition of the colloid extracted from the B horizon, being shown in Table 18.

TABLE 18.—*Chemical composition of Sassafras silt loam, Easton, Talbot County, Md.*[1]

Horizon	Depth	Chemical [2]														
		SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*
A	0– 8	[a]82. 88	1. 09	2. 25	7. 49	0. 04	0. 41	0. 36	1. 87	0. 90	0. 15	0. 05	2. 97	100. 57	0. 070	------
		[b]85. 41	1. 12	2. 32	7. 72	. 04	. 42	. 37	1. 93	. 93	. 16	. 05	------	100. 47	------	------
B	8–22	[a]75. 45	1. 05	4. 45	11. 89	. 03	. 40	. 55	2. 06	1. 09	. 21	. 02	3. 36	100. 56	. 030	------
		[b]78. 07	1. 09	4. 60	12. 30	. 03	. 41	. 57	2. 13	1. 13	. 22	. 07	------	100. 63	------	------
		[c]41. 14	. 70	12. 73	29. 26	. 03	. 53	1. 07	1. 35	. 42	. 08	. 07	14. 08	101. 46	. 320	------
		[d]47. 88	. 81	14. 82	34. 12	. 04	. 61	1. 24	1. 57	. 48	. 09	. 08	------	101. 74	------	------

[1] Collected by H. H. Bennett.
[2] Analyzed by W. O. Robinson and R. S. Holmes.

Material from the C horizon was not analyzed so that no comparison can be made between either horizon of the solum and the parent material. Since the percentage of quartz silica in any of the sandy soils of the Gray-Brown Podzolic soils of the coastal plain has never been determined it is not yet possible to determine the silica-alumina ratio from the composition of the whole soil less the quartz silica. The composition of the colloid gives a means of doing this since the colloid contains no quartz silica or, if any, a very small percentage. The silica-alumina ratio (sa) of the colloid would give at least the approximate ratio of silica to the combined alumina. In the Talbot County sample this is 2.4. This indicates that leaching of silicate-silica has not yet advanced beyond the kaolinitic stage.

Because of the smooth relief, good drainage, and the occurrence of slightly more sandy material, seemingly a geological matter, below the solum, the Sassafras soils of the Eastern Shore of Virginia are good representatives of the series. Because of their normal development, the presence of the characteristic features of the profile, the smooth relief, and mild climate, the area, though small, constitutes an extremely important agricultural district. A sample of the sandy loam was collected 2 miles south of Temperanceville, Accomac County, Va., and subjected to analysis. The results are shown in Table 19.

TABLE 19.—*Composition of Sassafras sandy loam, Temperanceville, Accomac County, Va.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P.ct.*	*Per ct.*	*P. ct.*	*P. ct.*
29422	A_1	0–¾	[a]88. 73	0. 17	3. 84	1. 79	0. 02	0. 08	0. 18	0. 51	0. 17	0. 01	0. 12	4. 23	99. 85	0. 090	------
			[b]92. 62	. 18	4. 01	1. 87	. 02	. 08	. 19	. 53	. 18	. 01	. 13	------	99. 82	------	------
29423	A_2	¾–16	[a]93. 78	. 24	. 80	3. 02	. 01	. 28	. 30	. 55	. 20	. 02	. 04	1. 35	100. 59	. 020	------
			[b]95. 04	. 24	. 81	3. 06	. 01	. 28	. 30	. 56	. 20	. 02	. 04	------	100. 57	------	------
29424	B	16–30	[a]91. 64	. 29	1. 43	3. 83	. 01	. 22	. 42	. 61	. 16	. 01	. 03	1. 45	100. 10	. 023	------
			[b]92. 98	. 29	1. 45	3. 89	. 01	. 22	. 43	. 62	. 16	. 01	. 03	------	100. 05	------	------
29425	C	30–40	[a]93. 70	. 01	1. 08	3. 51	. 01	. 28	. 23	. 45	. 19	. 02	. 09	1. 14	100. 71	. 020	------
			[b]94. 77	. 01	1. 09	3. 55	. 01	. 28	. 23	. 46	. 19	. 02	. 09	------	100. 70	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29422	A_1	0–¾	2. 6	31. 6	24. 6	22. 6	1. 5	11. 9	5. 1	99. 9
29423	A_2	¾–16	1. 9	24. 7	23. 1	24. 6	2. 0	19. 0	4. 5	99. 8
29424	B	16–30	1. 6	33. 8	28. 9	13. 6	1. 2	12. 3	8. 6	100. 0
29425	C	30–40	2. 1	36. 4	34. 0	16. 3	. 2	3. 7	7. 2	99. 9

[1] Collected by C. F. Marbut.
[2] Analyzed by R. S. Holmes, S. Mattson, G. Edgington, I. A. Denison, and G. J. Hough.
[3] Analyzed by A. A. White.

The complete analysis shows moderate apparent concentration of sesquioxides in the B horizon and low percentages of alkalies and alkaline earths throughout the profile. The content of potash in B is a little higher than in any of the other horizons, but those of calcium oxide and soda are lower.

The sa, ba, and sf ratios for the A_2, B, and C horizons, and the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 20.

TABLE 20.—*Sassafras sandy loam, Temperanceville, Va.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
29423	A_2	¾–16	52. 6	82. 03	0. 5039	1. 576	0. 0050	0. 0300
29424	B	16–30	40. 6	63. 31	. 3437	1. 541	. 0090	. 0380
29425	C	30–40	45. 4	70. 74	. 3724	1. 571	. 0068	. 0347

Because of the high percentage of silica present in the form of quartz the sa and sf ratios are large. Both of the sesquioxides involved in the sa and sf ratios have been shifted from the A_2 horizon and accumulated in the B. The number of molecules of alumina in B is, relative to silica, about 12 per cent greater than in C and about 30 per cent greater than in A. Not all alumina removed from A has accumulated in B. This is indicated by the molecular equivalent composition as well as by the ba ratio.

The number of iron oxide molecules in B, relative to those of silica, is about a tenth greater than in C but is about 30 per cent greater than in A. A similar relationship is shown by the molecular equivalent composition.

Although the percentage of alumina in B is greater than in A_2 or C and that of clay shown by the mechanical composition table is also higher, the ba ratios show a lower number, relative to alumina, of alkalies and alkaline earths in B than in either C or A_2. Since the percentage of feldspathic mineral or of any primary minerals other than quartz is very low, the alumina is presumably present mainly in colloid form. It is apparent, therefore, that it is not so near saturation with bases in B as in A_2 or C.

As already explained, the Sassafras soils are the soils of the northern coastal plain developed to maturity under good drainage and from unconsolidated deposits containing little or no lime carbonate, primary minerals, or complex rapidly decomposing secondary minerals. The materials are dominantly quartz, and various decomposition products designated as clay. It is highly probable that some soils have been identified as members of the Sassafras series that have developed from materials containing glauconite, the material from which the Collington soils have developed. It is not surprising that this may have taken place, nor was it necessarily a mistaken identification. The Sassafras soils are the most advanced in stage of development of the important soils of the northern coastal plain. This is equivalent to saying that they are the most thoroughly leached and eluviated.

Given time or relatively rapid soil development, a Sassafras soil could be developed from any kind of parent material.

The Sassafras soils of New Jersey occupy a belt running along the inner border of the coastal plain and occur in small areas throughout the sandy coastal belt of the State. They occupy large areas in Maryland, Delaware, and eastern Virginia.

COMPOSITION OF COLLINGTON SOILS

Collington soils differ from Sassafras soils in their derivation from unconsolidated deposits containing a high percentage of glauconitic sand, and from such differences as arise from the slower rate of profile development in this material than in ordinary sands and clays, such as those from which the Sassafras soils have developed.

TABLE 21.—*Composition of Collington loam, Prince Georges County, Md.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
29676	A_0	0–1	[a]79.00	0.76	2.50	3.90	0.05	0.21	0.04	1.02	0.27	0.11	0.10	12.03	100.00	2.940	------
			[b]89.80	.86	2.84	4.44	.06	.24	.05	1.16	.31	.13	.11	------	100.00	------	------
29677	A_1	1–12	[a]87.98	.85	2.91	4.67	.01	.21	.32	1.45	.40	.09	.04	1.79	100.72	.030	------
			[b]89.51	.87	2.96	4.75	.01	.21	.33	1.48	.41	.09	.04	------	100.66	------	------
29678	A_2	13–18	[a]87.09	.92	4.29	3.54	.01	.41	.49	1.62	.40	.10	.05	1.67	100.50	.020	------
			[b]88.58	.93	4.36	3.60	.01	.42	.50	1.65	.41	.10	.05	------	100.60	------	------
29679	B	18–40	[a]77.71	.82	9.44	5.20	.01	.30	1.09	2.91	.30	.12	.04	2.98	100.92	.025	------
			[b]80.08	.85	9.73	5.36	.01	.31	1.12	3.00	.31	.12	.04	------	100.93	------	------
29680	C_1	40–45	[a]77.65	.47	12.23	2.52	.01	.28	1.25	2.51	.30	.12	.24	3.01	100.59	.020	------
			[b]80.06	.47	12.60	2.60	.01	.29	1.29	2.59	.31	.12	.25	------	100.59	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
29676	A_0	0–1	0.0	8.6	5.6	46.8	13.1	16.4	9.4	99.9
29677	A_1	1–12	.2	3.7	6.2	51.8	12.1	17.9	8.0	99.9
29678	A_2	13–18	.2	4.0	6.4	49.8	14.0	17.5	8.0	99.9
29679	B	18–40	.5	4.4	5.8	45.4	11.8	10.8	21.3	100.0
29680	C_1	40–45	.4	11.0	18.9	49.9	3.0	4.1	12.8	100.1

[1] Collected by C. F. Marbut.
[2] Analyzed by G. Edgington and R. S. Holmes.
[3] Analyzed by A. A. White.

The results of a complete fusion analysis of samples from a Collington profile in Prince Georges County, Md., are shown in Table 21. The first cross column of the table shows the composition of the leaf mold. The A horizon extends to a depth of 18 inches and the B to 40 inches. The percentages of silica, alumina, and iron in the several layers of the A horizon are quite uniform except in A_2, where the percentage of iron oxide is somewhat high and alumina correspondingly low. The percentage of iron oxide in C is higher than in B because of the high iron content in glauconite and the percentage of alumina is slightly lower. The percentage of potash also is higher in the lower part of C than in B and nearly twice that in A. Magnesia runs about parallel to potash and iron and both run about parallel with loss on ignition. There is an apparent accumulation of alumina in the B horizon, but loss of iron, compared with that in C, in both A and B.

The sa ratios for A_2, B, and C_1 and the molecular equivalent composition in SiO_2, Al_2O_3, and Fe_2O_3 are shown in Table 22.

TABLE 22.—*Collington loam, Prince Georges County, Md.*

Sample No.	Horizon	Depth in inches	Ratios sa	sf	ba	Molecular equivalent composition SiO₂	Fe₂O₃	Al₂O₃
29678	A_2	13–18	32.0	80.0	0.558	1.470	0.027	0.035
29679	B	18–40	25.4	22.0	.808	1.328	.061	.052
29680	C_1	40–45	52.3	17.0	1.480	1.327	.079	.025

The sa ratios and molecular equivalent composition show more than twice as much alumina in the B than in the C horizon but a loss of iron in both the A and B horizons. That in the B horizon is nearly 30 per cent less than in C, while that in A is less than 40 per cent of that in C.

The accumulation in this soil is clearly one of alumina only, but there is no associated accumulation of organic matter in B suggesting that it belongs with the true Podzols and has developed an organic orterde. The amount of organic matter decreases progressively downward from the surface.

A profile of Collington loamy fine sand, 2 miles south of Auburn, N. J., was studied and samples collected for chemical and mechanical analysis. The results are shown in Table 23.

TABLE 23.—*Composition of Collington loamy fine sand, Auburn, N. J.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
29441–2	A_1	0–3	[a]90.58	0.56	1.44	1.56	0.01	0.26	0.22	0.31	0.38	0.09	0.22	4.96	100.59	0.160	------
			[b]95.03	.59	1.52	1.64	.01	.27	.23	.33	.40	.09	.23	------	100.58	------	------
29443	A_2	3–24	[a]95.19	.62	2.11	.50	.01	.31	.18	.22	.52	.09	.15	.95	100.85	.050	------
			[b]96.10	.63	2.13	.50	.01	.31	.18	.22	.52	.09	.15	------	100.82	------	------
29444	B	24–36	[a]87.24	.50	1.28	7.10	.01	.19	.33	.36	.56	.36	.21	1.51	99.65	.040	------
			[b]88.55	.51	1.30	7.20	.01	.19	.33	.37	.57	.37	.21	------	99.61	------	------
29445	C	36–60	[a]64.76	.67	13.54	9.30	.04	.04	2.06	4.37	.97	.11	.07	4.37	100.29	.010	------
			[b]67.72	.70	14.17	9.72	.04	.04	2.15	4.57	1.01	.12	.07	------	100.31	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
29441–2	A_1	0–3	1.5	7.6	17.2	52.9	5.8	8.9	5.8	99.7
29443	A_2	3–24	.4	9.0	22.6	54.6	3.4	7.0	3.1	100.1
29444	B	24–36	.2	7.4	18.6	47.7	7.1	9.3	9.7	100.0
29445	C	36–60	.6	9.3	13.8	30.4	7.1	9.9	28.9	100.0

[1] Collected by C. F. Marbut.
[2] Analyzed by I. A. Denison.
[3] Analyzed by A. A. White.

In this table the chemical characteristics of typical Collington soils are well brought out. In this case the material contains a considerable sand constituent, facilitating the leaching of the soil and the rather rapid development of the profile. The thin A_1 horizon contains nearly 5 per cent of volatile matter, most of which consists of dark-colored organic matter. The percentages of alumina and iron are low in both the A and B horizons, the B horizon containing a rather high percentage of alumina but not so much as in C. The percentages of iron, alumina, and potash are all high in C. The percentage of magnesia is high also but that of CaO is very low. The leaching of sesquioxides and all the bases from the solum is so clear that it is unnecessary to calculate the several ratios or the molecular equivalent composition to make this relation evident.

Collington soils occur in general on smooth or gently undulating relief. Ground water lies several feet below the solum but the smooth relief has not favored excessive oxidation. In a few localities, because of relatively steep slope and the presence of a high percentage of coarse sand, oxidation has been thorough, and the soil has assumed a well-defined reddish color. Such a soil, designated as Colts Neck sandy loam, occurs in the vicinity of Colts Neck, N. J. The chemical and mechanical composition are shown in table 24.

The occurrence of this soil on a slope and its subjection to active erosion have prevented the development of a highly eluviated profile and a light-colored A horizon. All the horizons are red or reddish. The percentage of silica, sesquioxides, and potash are not widely different in the various horizons. The relatively high silica and low alumina and iron oxide in the surface layer show that podzolization has been going on, but the solum does not show the differences shown in the Collington profile at Auburn, N. J. Oxidation extends below a depth of 72 inches. It is evident that the Podzolic profile is faintly developed because of the occurrence of this soil on a slope and the resulting erosion, but such occurrence has favored thorough and deep oxidation and probably also partial dehydration.

TABLE 24.—*Composition of Colts Neck sandy loam, Red Valley, N. J.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
29457	A	0–12	[a]86.80	0.47	6.52	3.08	0.01	0.44	0.18	0.68	0.08	0.12	0.05	2.08	100.51	0.030	------
			[b]88.65	.48	6.65	3.14	.01	.45	.18	.69	.08	.12	.05	------	100.50	------	------
29458	B_1	12–30	[a]75.56	.48	12.46	5.17	.01	.34	.34	1.05	.40	.34	.12	3.34	99.60	.020	------
			[b]78.18	.50	12.88	5.35	.01	.35	.35	1.09	.41	.35	.12	------	99.56	------	------
29459	B_2	30–48	[a]74.80	.24	14.45	4.86	.01	.57	.46	1.22	.36	.34	.10	3.55	100.95	.014	------
			[b]77.46	.25	14.98	5.04	.01	.59	.48	1.27	.37	.35	.10	------	100.97	------	------
29460	C	48–72	[a]78.23	.19	11.67	5.14	.01	.52	.42	1.17	.48	.38	.06	2.84	101.11	.010	------
			[b]80.53	.20	12.02	5.29	.01	.54	.43	1.20	.49	.39	.06	------	101.16	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	Per cent	Per cent	Per cent	Per cent	Per cent	Per cen	Per cent	Per cent
29457	A	0–12	1.2	19.2	38.3	16.3	2.8	8.8	13.5	100.1
29458	B_1	12–30	1.8	21.1	33.6	10.4	2.4	3.9	26.9	100.1
29459	B_2	30–48	2.1	23.2	36.5	11.1	3.0	6.4	17.8	100.1
29460	C	48–72	4.9	28.0	38.6	10.0	1.6	5.9	10.8	99.8

[1] Collected by C. F. Marbut.
[2] Analyzed by R. S. Holmes, S. Mattson, G. Edgington, G. J. Hough, and I. A. Denison.
[3] Analyzed by L. T. Alexander.

COMPOSITION OF CHESTER SOILS

The Chester soils have developed from material accumulated by decomposition in place of crystalline schists and gneisses, and they have the well-developed color and texture profile of the Gray-Brown Podzolic group. In the vicinity of Washington, D. C., they have developed from granitoid gneiss.

Samples were collected in Lee Heights, Va., a suburb of Washington and from Glenmont and Rockville, Md., and subjected to complete chemical analysis. The Lee Heights sample was collected by horizons, including the loose material below the B horizon designated as C_1. The Glenmont and Rockville samples did not include this material. No rock sample was collected from these localities, but a sample of the gneiss was collected by the late Dr. George B. Merrill (*14*) near Washington, many years ago and analyzed by him. The results of both chemical and mechanical analyses are shown in Table 25.

TABLE 25.—*Composition of Chester loam, Lee Heights, Arlington County, Va.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	P. c	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
33975	A	½–4	[a]75.24	1.43	4.19	11.09	0.05	0.20	0.52	2.22	0.88	0.06	0.08	3.83	99.79	0.030	------
			[b]78.22	1.49	4.36	11.53	.05	.21	.54	2.31	.91	.06	.08	------	99.75	------	------
33976	B_1	12–18	[a]62.97	1.20	6.75	17.92	.03	.24	.89	2.46	.98	.08	.03	6.06	99.61	.040	------
			[b]67.01	1.28	7.19	19.08	.03	.26	.95	2.62	1.04	.09	.03	------	99.60	------	------
			[c]36.60	.56	15.62	28.91	.05	.52	1.26	1.11	.17	.19	.20	------	95.41	[3] 4.16	------
			[d]38.19	.58	16.30	30.17	.05	.54	1.32	1.16	.18	.20	.21	------	99.57	------	------
33977	B_2	30–36	[a]61.50	1.01	7.94	19.20	.05	.20	1.08	3.08	1.01	.10	.03	5.10	100.33	.003	------
			[b]64.81	1.06	8.36	20.23	.05	.21	1.14	3.20	1.10	.11	.03	------	100.30	------	------
33978	C	45+	[a]66.14	1.00	6.94	16.85	.06	.20	.96	2.58	.73	.08	.02	4.31	99.87	.000	------
			[b]69.11	1.04	7.26	17.62	.06	.21	1.00	2.70	.76	.08	.02	------	99.90	------	------
Gneissoid granite[4]	------	------	69.33	------	3.99	14.33	------	3.21	2.44	2.67	2.70	0.10	------	------	98.77	------	------

Sample No.	Horizon	Depth	Mechanical [5] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
33975	A	½–4	0.5	3.5	4.6	21.4	12.8	44.9	12.5	100.2
33976	B_1	12–18	.2	1.3	2.0	13.1	8.3	40.9	34.0	99.8
33977	B_2	30–36	.5	5.4	7.4	33.8	11.9	27.5	14.0	100.5
33978	C	45+	.6	8.6	9.5	38.8	14.5	22.6	5.7	100.3

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough.
[3] Organic matter.
[4] Rock from Rock Creek Park, District of Columbia, U. S. A.
[5] Analyzed by J. B. Spencer.

The Lee Heights sample, the only one collected strictly by horizons, shows in typical form the usual features of the Podzolic chemical profile. The content of silica is high in A, low in B, and high again in C though not so high as in A, whereas that of iron oxide and of alumina is low in A, high in B, and low again in C but not so low as in A. The percentages of CaO and Na_2O are low throughout the profile and that of potash is relatively high, being highest in B_2. Table 26 shows the

sa, ba, and sf ratios and the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3.

TABLE 26.—*Chester loam, Lee Heights, Arlington County, Va.*

Horizon	Ratios			Molecular equivalent composition			
	sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
A	11.54	47.56	0.376	1.302	0.0273	0.113	0.0424
B_1	6.111	24.69	.263	1.116	.0454	.187	.0496
C	6.672	25.24	.259	1.152	.0455	.173	.0445
Colloid of B_1	2.14	6.21	.081	.744	.1190	.343	.0282
Rock	8.22	45.93	.920	1.150	.0250	.140	.1290

These figures show a number of interesting things. The content of silica in the C horizon, according to the molecular equivalent composition table, is essentially the same as that in the rock and that in the B horizon is practically the same, being less than 4 per cent lower than in the rock. In the A horizon there is a well-defined accumulation, but it is not large, being about 14 per cent more than that in the rock.

The relative number of iron oxide molecules in the B_1 and C horizons, however, is about twice the number in the rock.[13]

The iron oxide content of the A horizon is almost identical with that in the rock. That in both the B_1 and C horizons, however, is much higher than in the rock. An increase would be expected, but the percentage of increase is very large.

Accumulation of alumina has taken place in the B_1 and C horizons, but the A has suffered loss. The amount in the B_1 horizon is about 30 per cent more than the rock, in the C a little less than 25 per cent more, while that in the A is nearly 20 per cent less than in the rock.

The combined alkalies and alkaline earths, not including magnesia, have suffered heavy loss in all soil horizons, the amount in the B_1 horizon being greater than in C, according to the molecular equivalent composition, but according to the ba ratios the molecular ratios to alumina in B_1 and C are almost exactly the same. The number of molecules in the B_1 horizon is only a third of the number in the rock.

The loss of alkalies and alkaline earths has been suffered almost entirely in the process of rock decomposition and not in soil profile development. The A horizon seems to have lost a little to B_1, the latter having about 16 per cent more than the former. This shifting has been effected by processes of soil profile development but this is a shifting within the small amount of material left over from that lost in the process of rock decomposition.

Colloid material was extracted by Holmes and Edgington (*10*) from the B_1 horizon of the Chester profile and subjected to complete chemical analysis. The results are shown in Table 25, and the several factors developed from it are shown in the last line but one of Table 26.

These results show that 40 per cent of the silica has been lost in the change from rock to colloidal material, the iron expressed as oxide has been multiplied nearly 5 times, and alumina has been increased by about 120 per cent. The alkalies and alkaline earths have suffered about 75 per cent loss, about twice that of silica.

Holmes and Edgington (*10*) of the Bureau of Chemistry and Soils, have completed an extensive study of the colloid from the soils of a number of representative and important soil series. These include the soils of the Miami, Chester, and Cecil series, all being important series in the Pedalfers of the United States. One of the important conclusions is that the character of the colloid in different soil series is different but that in soils of the same series is much alike throughout all horizons of the profile.

Robinson and Holmes (*15*) extracted colloid from a sample of Chester loam from Glenmont, Md., determined its composition as well as that of the whole soil but did not collect material from the C horizon or underlying consolidated metamorphic rock.

The sa ratio in the colloid of 2.2 supplements the evidence contained in the same ratio in the colloid of the Lee Heights, Va., sample that the kaolinitic decomposition of the silicate minerals in the Virginia-Maryland latitude has not gone over the boundary into lateritic weathering.

COMPOSITION OF NASON, MANOR, AND LEONARDTOWN SOILS

Nason soils have been included with the Chester on the soil map and do not appear as Nason. They lie on the piedmont plateau in Orange County, Va., have a Podzolic profile, have a B horizon somewhat more red than that of the Chester in Maryland and northward, and have developed from a fine-grained schist which has not been analyzed. The relief is smoother than that of the Chester soils in the vicinity of Washington.

The composition of samples of Nason loam from Orange County, Va., carefully collected by horizons is shown in Table 27. The sample from the A horizon does not include the very thin (2-inch) layer of soil impregnated with organic matter. The complete fusion analysis shows high content of silica and low content of iron oxide and alumina in the A horizon and low content of silica with high alumina in the B horizon. The C horizon, the distintegrated schist, has a composition intermediate between that of A and B.

TABLE 27.—*Composition of Nason loam, Scuffletown, Orange County, Va.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
35074	A	2-8	[a]81.96	1.10	2.67	6.62	0.03	0.24	0.30	1.20	0.02	0.09	0.09	5.48	99.80	0.080	------
			[b]86.70	1.16	2.82	7.01	.03	.25	.32	1.27	.02	.09	.09	------	99.76	------	------
35075	B	12-30	[a]50.36	1.21	12.82	23.61	.03	.16	.37	1.13	.08	.14	.10	9.50	99.51	.014	------
			[b]55.65	1.34	14.17	26.11	.03	.18	.41	1.25	.09	.15	.11	------	99.49	------	------
35076	C	36-72	[a]64.14	.90	7.27	17.69	.04	.14	.75	2.32	.02	.10	.07	6.53	99.97	.008	------
			[b]68.66	.96	7.78	18.92	.04	.15	.80	2.48	.02	.11	.07	------	99.99	------	------

[1] Collected by B. H. Hendrickson.
[2] Analyzed by G. J. Hough.

[13] Calculated after reducing the FeO (3.6) to its equivalent in Fe_2O_3 (4).

TABLE 27.—*Composition of Nason loam, Scuffletown, Orange County, Va.*—Continued

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
35074	A	2-8	1.1	4.5	9.3	21.2	14.7	28.7	20.4	99.9
35075	B	12-30	.6	1.8	3.2	8.2	6.8	13.0	66.4	100.0
35076	C	36-72	.1	.2	.3	16.3	32.5	30.6	19.9	99.9

[3] Analyzed by L. T. Alexander.

The ratios for the three horizons and the molecular equivalent composition are shown in Table 28.

TABLE 28.—*Nason loam, Scuffletown, Orange County, Va.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
35074	A	2-8	21.00	81.47	0.266	1.4400	0.0176	0.0687	0.018
35075	B	12-30	3.60	10.65	.070	.9200	.0887	.2557	.018
35076	C	36-72	6.17	23.45	.157	1.138	.0486	.1856	.029

These results indicate an important accumulation of alumina in the B horizon compared with the C (the decomposed schist) and a very great loss from the A as compared with the C. Similar relationships are indicated by the silica-iron oxide (sf) ratio, and the ba ratio shows a loss of alkalies and alkaline earths from B and a great loss in A when compared with C. The sa and sf ratios show that in this case both iron oxide and alumina have accumulated in the B horizon, and in each case the ratios in B are only about half those in C. Eluviation here has involved both constituents to a much greater extent than in any of the soils previously discussed.

The southern boundary of the Gray-Brown Podzolic soils has been determined mainly on the basis of soil morphology. Not enough is known about the chemical characteristics of the soils along the probable boundary to make, as yet, an exact location possible. The Nason soils have been subjected to more thorough eluviation and leaching than has taken place in the soils farther north, showing probably the influence of a more southern latitude. This conclusion, however, is not entirely convincing since they occur on flatter relief than the Chester and Sassafras soils, and that fact alone would account for at least part of their more thoroughly eluviated profile.

The molecular equivalent composition of the three horizons of the Nason soils (Table 28) confirms or possibly expresses more clearly the relationships shown by the several ratios. The iron oxide in the B horizon is a little less than double that in C and the same is true of the alumina.

This discussion of the composition of the soils of the United States is concerned primarily with soils developed or developing under the influence of good drainage and free from other conditions which retard normal development or cause temporary "backward" development such as the presence of high percentages of lime carbonate in the form of clay or marl, high ground water, or long-enduring grass vegetation during the period of soil development. In a few cases, however, such soils have received some attention.

In the coastal-plain region, near Washington, D. C., certain remnants of an old smooth land surface, antedating the inauguration of the existing cycle of erosion, are still intact. A soil, Leonardtown silt loam, has developed on these areas under the influence of a ground water surface lying, it seems, at about 3 feet beneath the surface of the ground. An indurated layer has developed at this level (fig. 21). The A horizon, especially the lower part, has a highly laminated structure (fig. 22). Table 29 shows the chemical and mechanical composition of samples from the horizons of Leonardtown silt loam from the District of Columbia.

TABLE 29.—*Composition of Leonardtown silt loam, Washington, D. C.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29651	A_1	0-¾	[a]78.67	1.02	1.96	5.28	0.02	0.71	0.53	1.16	0.79	0.07	0.14	10.25	100.60	0.230	------
			[b]87.64	1.14	2.18	5.88	.02	.79	.59	1.29	.88	.08	.16	------	100.64	------	------
29652	A_2	¾-4	[a]85.48	1.10	2.10	6.23	.02	.60	.34	1.20	.74	.07	.07	2.82	100.77	.040	------
			[b]87.98	1.13	2.16	6.41	.02	.62	.35	1.23	.76	.07	.07	------	100.80	------	------
29653	B_1	4-18	[a]82.17	1.20	3.74	8.14	.02	.44	.63	1.21	.55	.12	.10	2.84	101.15	.030	------
			[b]84.53	1.23	3.85	8.38	.02	.45	.65	1.25	.57	.12	.10	------	100.12	------	------
29654	B_2	18-28	[a]90.40	1.18	2.42	3.60	.02	.32	.42	.47	.38	.05	.05	1.36	100.66	.006	------
			[b]91.62	1.20	2.45	3.65	.02	.32	.43	.48	.39	.05	.05	------	100.66	------	------
29655	C	36+	[a]72.33	1.04	5.75	13.87	.01	.37	.43	.63	.31	.08	.03	5.25	100.09	.010	------
			[b]76.31	1.10	6.06	14.64	.01	.39	.45	.66	.33	.08	.03	------	100.06	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29651	A_1	0-¾	2.2	6.0	3.6	11.8	8.5	55.7	12.1	99.9
29652	A_2	¾-4	.0	6.7	3.6	11.5	12.8	53.2	12.0	99.8
29653	B_1	4-18	1.1	5.6	3.8	11.7	12.0	29.5	36.3	100.0
29654	B_2	18-28	2.1	9.9	6.9	23.1	20.2	21.9	15.8	99.9
29655	C	36+	3.2	10.1	6.9	16.9	11.4	11.8	39.8	100.1

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough.
[3] Analyzed by A. A. White.

The A and B horizons show the usual characteristics of the Podzolic soils of the region. They are normal A and B Podzolic horizons but in the lower part of or below the B, an indurated layer has higher silica content than in A and considerably higher than in B or C. All the other constituents are low. It is possible that the induration is due to cementation by silica but that has not yet been definitely proved.

The several ratios as well as the molecular equivalent composition of this soil are shown in Table 30.

TABLE 30.—*Leonardtown silt loam, Washington, D. C.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
29652	A_2	¾–4	23.30	107.90	0.53	1.29	0.0135	0.0627
29653	B_1	4–18	17.15	58.15	.37	1.40	.0240	.0820
29654	B_2	18–28	42.70	99.10	.48	1.52	.0150	.0360
29655	C	36+	8.70	33.40	1.34	1.26	.0380	.1500

The sa ratio for B_2 is exceptionally high. This is caused by the high percentage of SiO_2 as well as the low percentage of Al_2O_3 in this horizon.

Leonardtown silt loam is the only one of the soils of this group of soils with indurated layers that has yet been analyzed. In this case there can be no question that the induration is accompanied by accumulation of silica. It is not known whether or not this will hold for all of these soils. Induration takes place through the accumulation of Fe_2O_3 or of calcium carbonate, but the identification of such horizons and the reason for their induration is easy. The Leonardtown, Lebanon, Rittman, and

FIGURE 21.—Detail of the A horizon of Leonardtown silt loam, near Washington, D. C., showing lamination.

other similar soils do not show by their color or effervescence in acid the kind of cementing material present.

The very low sa ratio in C is an expression of the high alumina present. It is geological and was originally different from the material converted into the solum. It is not the true parent material of the soil.

COMPOSITION OF HAGERSTOWN AND MAURY SOILS

The Hagerstown and Maury soils are Podzolic soils developed from material accumulated by the decomposition in place of limestones. A profile of Hagerstown silt loam at Murfreesboro, Tenn., was sampled a few years ago, though the C horizon seems not to have been reached. The chemical and mechanical composition are shown in Table 31.

TABLE 31.—*Composition of Hagerstown silt loam, Murfreesboro, Tenn.*[1]

Sample No.	Horizon	Depth	Chemical [2]													
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34713	A_1	0–4½	[a] 73.11	1.05	6.12	8.30	0.44	0.37	0.45	0.91	0.20	0.16	0.07	8.82	100.00	0.270	------
			[b] 80.18	1.15	6.71	9.10	.48	.41	.49	1.00	.22	.18	.08	------	100.00	------	------
34714	A_2	4½–11	[a] 75.98	1.08	5.82	9.18	.37	.25	.48	.93	.12	.11	Tr.	5.68	100.00	.120	------
			[b] 80.53	1.15	6.17	9.73	.39	.27	.51	.99	.13	.12	Tr.	------	99.99	------	------
34715	B_1	11–24	[a] 71.67	1.10	7.90	12.16	.27	.23	.49	.83	.04	.11	.06	5.14	100.00	.080	------
			[b] 75.55	1.16	8.32	12.82	.28	.24	.52	.87	.04	.12	.07	------	100.02	------	------
34716	B_2	24–36	[a] 67.10	1.17	8.64	14.10	.34	.13	.58	.80	.04	.15	.07	6.88	100.00	.030	------
			[b] 72.08	1.26	9.27	15.13	.36	.14	.62	.86	.04	.16	.08	------	100.00	------	------

[1] Collected by C. F. Marbut. [2] Analyzed in the division of soil chemistry, Bureau of Soils, Dec. 8, 1917.

TABLE 31.—*Composition of Hagerstown silt loam, Murfreesboro, Tenn.*—Continued

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34713	A_1	0–4½	8.2	5.8	1.5	1.8	1.5	54.7	26.4	99.9
34714	A_2	4½–11	5.2	5.1	1.5	1.7	1.5	47.3	37.6	99.9
34715	B_1	11–24	7.6	5.7	1.5	1.7	1.5	40.9	41.0	99.9
34716	B_2	24–36	5.9	7.0	1.8	2.1	1.8	35.1	46.4	100.1

[3] Analyzed by L. T. Alexander.

Since the C horizon was not sampled it is unnecessary to calculate the several factors shown in preceding tables. The podzolic character of the soil is shown in the low percentages of sesquioxides in the A horizon. The percentages of CaO, K_2O, and Na_2O are very slightly higher in A_1 than in the other horizons, owing to the presence of leaf mold. The percentage of sesquioxides is highest in the deepest layer sampled probably because this is part of the B horizon; but in limestone-derived material, accumulated through solution of lime carbonate rather than by decomposition of silicate minerals, it is not improbable that the material, immediately after being released by solution of the rock, contains a higher percentage of sesquioxides than in any higher horizon, at least until considerable thickness of material has accumulated.

Maury silt loam is Hagerstown silt loam developed from limestones containing a high percentage of phosphorus. Although the podzolic process has developed a profile definitely Podzolic, the leaching has not reduced the percentage of P_2O_5 to what it is in the Hagerstown soils.

A profile near Ashwood, Maury County, Tenn., was studied, sampled, and analyzed, the results being shown in Table 32. The soil is somewhat lighter in texture than Hagerstown silt loam but the difference is small. The percentage of silica is somewhat higher than in the Hagerstown soil and that of sesquioxides is lower. The percentage of P_2O_5 ranges from 0.33 per cent to 0.58 per cent, or from about twice the usual percentage in a good soil to approximately four times as much in the lowest

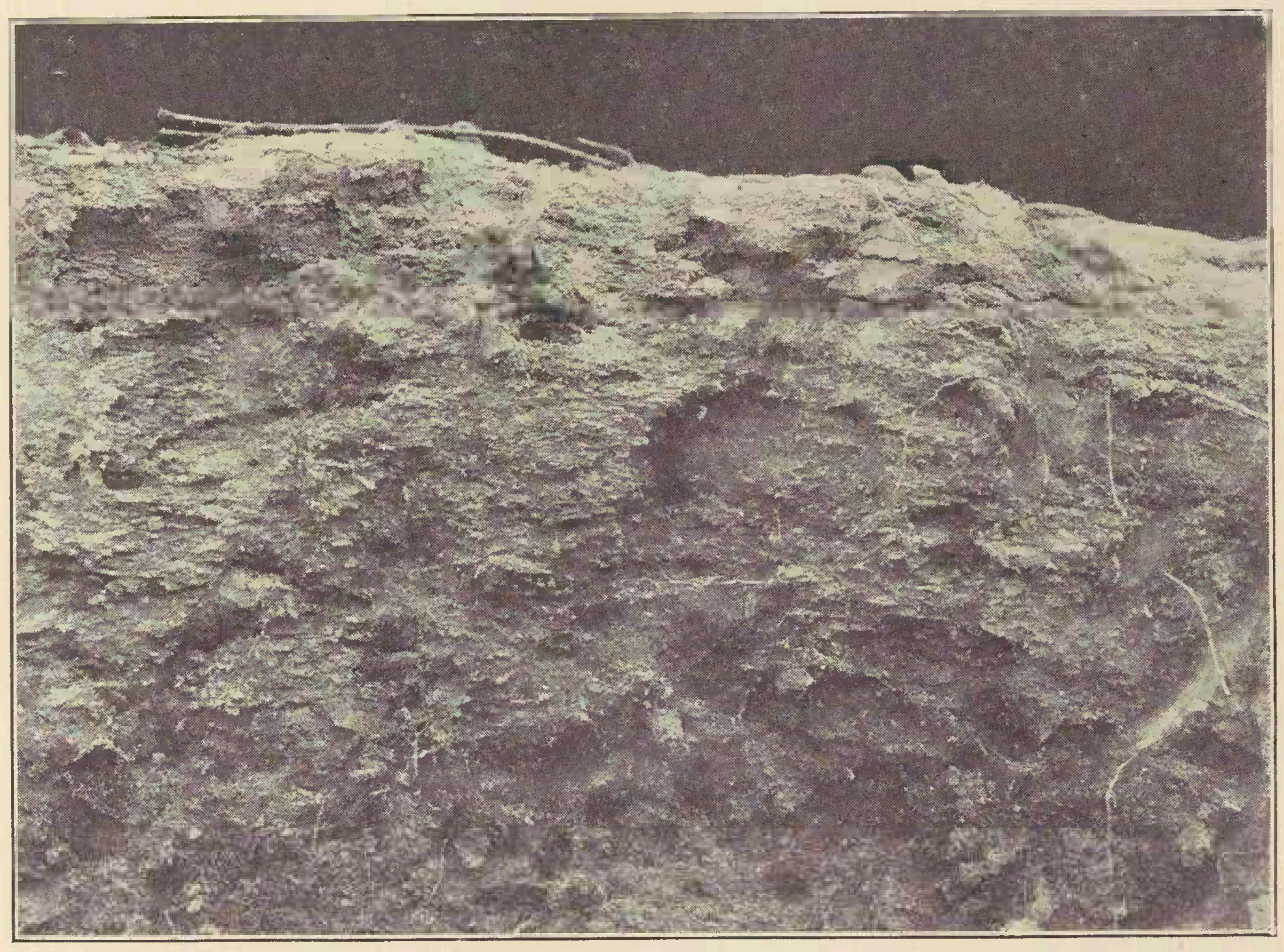


FIGURE 22.—Profile of Leonardtown silt loam, near Washington, D. C., showing detail of lamination in A horizon.

horizon sampled. Leaching has probably reduced the percentage in all the horizons, since most of the readily attacked materials are removed during the accumulation of the soil material by solution of the limestone.

TABLE 32.—*Composition of Maury silt loam, Ashwood, Tenn.*[1]

Sample No.	Horizon	Depth	Chemical [2]													
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28499	A_1	0–12	[a] 78.14	1.69	3.61	7.24	0.35	0.86	0.26	1.59	0.43	0.31	0.10	5.17	99.75	0.150	------
			[b] 82.41	1.78	3.80	7.63	.37	.91	.27	1.68	.45	.33	.11	------	99.74	------	------
28500	A_2	12–20	[a] 78.10	1.41	3.59	9.14	.44	.66	.37	1.59	.48	.31	.13	4.25	100.57	.120	------
			[b] 81.58	1.47	3.75	9.54	.46	.69	.39	1.66	.50	.32	.14	------	100.50	------	------
28501	B	20–30	[a] 74.91	1.41	4.39	12.13	.31	.48	.46	1.51	.32	.36	.12	3.82	100.22	.100	------
			[b] 77.88	1.47	4.56	12.61	.32	.50	.48	1.57	.33	.37	.12	------	100.21	------	------
28502	C	30–42	[a] 72.16	1.52	5.82	13.18	.57	.49	.52	1.35	.22	.55	.11	4.57	101.06	.090	------
			[b] 75.58	1.59	6.10	13.82	.60	.51	.54	1.41	.23	.58	.12	------	101.08	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28499	A_1	0–12	0.7	1.5	0.5	1.1	7.0	69.8	19.2	99.8
28500	A_2	12–20	.0	1.7	.6	1.3	7.7	66.2	22.6	100.1
28501	B	20–30	.7	2.6	.7	1.4	9.9	55.9	28.9	100.1
28502	C	30–42	.3	3.4	1.3	2.3	11.1	48.6	32.9	99.9

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Oct. 29, 1920.
[3] Analyzed by A. A. White.

COMPOSITION OF ONTARIO SOILS

The Ontario soils occur in the lowland belt south and east of Lake Ontario in New York. They have developed from glacial drift containing a rather high percentage of lime carbonate as finely divided material and limestone fragments. The profile is very faintly developed, but enough development has taken place to show that they belong to the Gray-Brown Podzolic soils. Table 33 shows the chemical

and mechanical composition of samples from a profile of Ontario silt loam from Lansingville, Ontario County, N. Y. It shows an apparent concentration of alumina in B, but when the analysis has been recalculated to eliminate the loss on ignition the per cent in C becomes 11.08, almost as much as in B. The percentages of both potash and soda range from good to high, but that of lime above the C horizon is low. These are relatively productive soils. The percentage of organic matter is higher than in most of the soils of the Gray-Brown Podzolic group, and the soils are highly silty in texture.

TABLE 33.—*Composition of Ontario silt loam, Lansingville, Ontario County, N. Y.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
163220	A	0–10	[a]76.54	0.64	3.43	9.38	0.08	0.80	0.75	1.95	1.04	0.10	0.08	5.30	100.09	0.157	------
			[b]80.82	.68	3.62	9.91	.09	.84	.79	2.06	1.10	.11	.08	------	100.10	------	------
163221	B	10–24	[a]76.32	.66	4.12	11.23	.08	.59	.93	2.25	1.02	.07	.06	3.01	100.34	.080	------
			[b]79.00	.68	4.25	11.57	.09	.61	.96	2.32	1.05	.07	.06	------	100.34	------	------
163222	C	24–36	[a]60.94	.49	3.00	8.72	.07	9.44	3.57	1.82	.87	.10	.03	11.28	100.33	.029	9.92
			[b]68.70	.55	3.38	9.83	.07	10.64	4.02	2.05	.98	.11	.03	------	100.36	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
163220	A	0–10	1.0	2.8	2.6	19.2	25.3	36.5	12.7	100.1
163221	B	10–24	1.2	3.5	2.7	18.3	22.3	37.2	15.0	100.2
163222	C	24–36	2.4	4.6	2.9	17.3	22.6	37.8	12.5	100.1

[1] Collected by F. B. Howe.
[2] Analyzed by G. Edgington.
[3] Analyzed by A. A. White.

The ratios for the three horizons of Ontario silt loam and the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 34.

TABLE 34.—*Ontario silt loam, Lansingville, Ontario County, N. Y.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
163220	A	0–10	13.86	59.16	0.398	1.34	0.0226	0.097
163221	B	10–24	11.61	48.01	.463	1.31	.0266	.113
163222	C	24–36	11.88	53.86	2.362	1.13	.0211	.096

The sa ratios in horizons B and C differ very slightly. The molecular equivalent quantities for the same two horizons differ to a much greater extent because of the presence in C of a high percentage of calcium carbonate. The sa ratios express more accurately the relationships of the two horizons in sesquioxides and silica. The accumulation of alumina in B has been very slight if any at all, but the loss from A has been more important. Apparently the accumulation of iron oxide in B has taken place to a greater extent than that of alumina.

Colloid was extracted from the B horizon of Ontario loam from New York. The silica-alumina ratio is 2.9, a good deal higher than that of the soils from limestone material in Tennessee or of the soils in the vicinity of Washington, D. C. The same ratio in the whole soil is more than 11, showing the presence of a considerable percentage of quartz.

COMPOSITION OF GLOUCESTER AND MERRIMAC SOILS

Gloucester and Merrimac soils are mainly New England soils. They have developed from glacial deposits derived from crystalline gneisses and schists. The results of complete chemical and mechanical analyses of samples from a Gloucester profile in Berkshire County, Mass., are shown in Table 35.

TABLE 35.—*Composition of Gloucester fine sandy loam, Hinsdale, Berkshire County, Mass.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1307136	A_1	0–3	[a]65.91	0.66	3.82	8.97	0.11	1.18	0.77	2.50	1.34	0.13	0.11	14.26	99.76	0.344	------
			[b]76.88	.77	4.45	10.46	.13	1.38	.90	2.91	1.56	.15	.13	------	99.72	------	------
1307137	A_2	3–5	[a]72.86	.68	3.91	10.53	.09	.91	.54	2.33	1.37	.10	.08	6.32	99.72	.105	------
			[b]77.72	.73	4.17	11.23	.10	.97	.58	2.49	1.46	.11	.09	------	99.74	------	------
1307138	B	5–15	[a]74.79	.72	3.32	11.09	.06	1.11	.85	2.60	1.14	.15	.10	3.78	99.71	.050	------
			[b]77.71	.75	3.45	11.52	.06	1.15	.88	2.70	1.18	.16	.10	------	99.66	------	------
1307139	C_1	15–24	[a]74.13	.80	4.12	11.15	.07	1.52	.96	2.64	1.38	.17	.04	2.52	99.50	.020	------
			[b]76.02	.82	4.23	11.43	.07	1.56	.98	2.71	1.42	.17	.04	------	99.45	------	------
1307140	C_2	24–36	[a]76.03	.54	2.80	10.76	.05	2.54	.84	2.29	2.40	.21	.04	.98	99.48	.000	------
			[b]76.77	.55	2.83	10.87	.05	2.56	.85	2.31	2.42	.21	.04	------	99.46	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1307136	A_1	0–3	4.2	12.6	6.4	25.1	22.0	23.7	6.7	100.7
1307137	A_2	3–5	7.6	11.8	5.8	23.8	27.4	20.4	4.1	100.9
1307138	B	5–15	11.6	18.9	6.8	17.1	34.5	10.2	1.5	100.6
1307139	C_1	15–24	5.2	12.0	5.8	19.7	44.1	11.4	2.2	100.5
1307140	C_2	24–36	3.8	6.6	5.2	42.6	28.2	11.9	1.0	99.2

[1] Collected by W. J. Latimer.
[2] Analyzed by G. Edgington.
[3] Analyzed by R. W. Mahoney.

These results show great uniformity of composition for all horizons of the profile, including the parent glacial drift. The profile is much less well developed than the profiles of the Chester, Nason, and other soils from the southern part of the Gray-Brown Podzolic region. The percentage of silica ranges between 76 and a little less than 78, that of iron oxide between 3 and 4.5, and of alumina between 10.5 and 11.5. The range in the alkalies and alkaline earths is somewhat greater, the percentage of CaO ranging from 2.56 to 0.91 but those for K_2O and Na_2O are much smaller. Practically all that has taken place in such development as this soil has gone through is the accumulation of some organic matter, mainly overlying the soil, and the leaching of some of the alkalies and alkaline earths. Practically no eluviation has taken place. The percentages of all the alkalies and alkaline earths are highest in the upper 3 inches where the percentage of organic matter is high.

The ratios for three horizons and the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3 of Gloucester fine sandy loam from Berkshire County, Mass., are shown in Table 36.

TABLE 36.—*Gloucester fine sandy loam, Hinsdale, Berkshire County, Mass.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
1307137	A_2	3–5	11.76	49.39	0.612	1.29	0.026	0.1098
1307138	B	5–15	11.38	59.69	.605	1.29	.021	.1127
1307140	C_2	24–36	12.00	71.88	1.026	1.27	.018	.1063

The chemical and mechanical composition of a sample of Merrimac fine sandy loam from Foxboro, Mass., are shown in Table 37.

TABLE 37.—*Composition of Merrimac fine sandy loam, Foxboro, Mass.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28757	A_1	0–2½	[a]64.78	0.99	4.31	11.41	0.06	1.33	0.66	1.16	2.22	0.24	0.09	13.38	100.63	0.350	------
			[b]74.78	1.14	4.97	13.17	.07	1.53	.76	1.34	2.56	.28	.10	------	100.70	------	------
28758	A_2	2½–3½	[a]64.15	.97	3.83	9.93	.06	1.02	.71	1.14	2.20	.31	.17	15.62	100.11	.430	------
			[b]76.01	1.15	4.54	11.77	.07	1.21	.84	1.35	2.61	.37	.20	------	100.12	------	------
28759	B	3½–18	[a]69.17	.89	4.41	12.85	.06	1.40	.77	1.11	2.59	.39	.04	6.66	100.34	.150	------
			[b]74.09	.95	4.75	13.77	.06	1.45	.82	1.19	2.77	.42	.04	------	100.31	------	------
28760	C	18–28	[a]72.89	1.05	4.25	11.60	.07	1.57	.91	1.22	2.06	.15	.02	4.06	99.85	.090	------
			[b]75.98	1.09	4.43	12.08	.07	1.64	.95	1.27	2.15	.16	.02	------	99.82	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28757	A_1	0–2½	3.1	14.4	15.1	42.8	4.7	11.1	8.7	100.0
28758	A_2	2½–3½	2.7	13.0	16.5	47.6	3.7	9.6	7.0	100.1
28759	B	3½–18	1.6	16.1	12.8	24.8	15.5	22.3	6.9	100.0
28760	C	18–28	3.2	14.8	16.4	36.5	9.7	15.4	4.0	100.0

[1] Collected by C. F. Marbut. [2] Analyzed by F. A. Barker. [3] Analyzed by A. A. White.

The dark-colored surface layer to a depth of 2½ inches is high in organic matter and contains a higher percentage of CaO than the thin underlying layer. There seems to be a slight accumulation of alumina and iron oxide in the layer extending from 3½ to 18 inches in depth. The range in composition in the several horizons is very small throughout. This is a young soil in which the Podzolic profile has not yet developed, except the accumulation of a slightly higher percentage of organic matter to a depth of 2½ or 3½ inches. This layer constitutes an incipient orterde. This sample is from New England, and its very light texture is such as to favor the development of a Podzol profile relatively early. Its occurrence in a region in which the Podzolic process is weak and where heavier soils would possibly retain a Gray-Brown Podzolic profile indefinitely rather than become a Podzol, indicates that the lighter soils may develop Podzol profiles in the Gray-Brown Podzolic region.

The mechanical composition shows a small percentage of clay throughout the profile, but the silt percentage ranges rather widely. The highest percentage, 22.3, in the layer between 3½ and 18 inches, probably consists mainly of free quartz, since the chemical composition for the same layer does not differ essentially from the other horizons. This is probably very fine sand.

COMPOSITION OF MIAMI AND ASSOCIATED SOILS

The Miami soils have developed from highly calcareous glacial drift, on smooth relief, and under good drainage conditions. The color and texture profiles are well developed. These are the dominant Gray-Brown Podzolic soils in western Ohio, most of Indiana, in southern Michigan, and in southern Wisconsin. (See soil map, pl. 5, secs. 2 and 7.)

The chemical (fusion analysis) and mechanical composition of four samples of Miami soils are shown in Tables 38, 40, 43, and 44. In all cases the samples were carefully collected by horizons and represent virgin soils. The sample of the silt loam from Hancock County, Ind., Table 38, is representative of the Miami group.

TABLE 38.—*Composition of Miami silt loam, Greenfield, Hancock County, Ind.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
284018	A_1	0–2	[a]71.82	0.57	2.91	9.06	0.13	0.81	0.62	2.02	1.06	0.13	0.13	11.09	100.35	0.334	------
			[b]80.79	.64	3.27	10.18	.14	.91	.70	2.27	1.19	.15	.15	------	100.39	------	------
284019	A_2	2–5	[a]77.08	.65	3.08	9.50	.14	.63	.64	2.03	1.02	.10	.07	5.00	99.94	.153	------
			[b]81.12	.68	3.24	10.00	.15	.66	.67	2.14	1.07	.11	.07	------	99.91	------	------
284020	A_3	5–12	[a]77.35	.65	3.22	10.09	.12	.53	.62	2.19	1.16	.08	.06	3.98	100.05	.104	------
			[b]80.52	.68	3.35	10.51	.13	.55	.65	2.23	1.21	.08	.06	------	100.11	------	------
	A_2 A_3	2–12	[c]47.47	.74	9.89	27.58	.28	.92	1.17	2.48	.34	.40	.29	9.23	100.79	------	------
			[d]52.30	.82	10.88	30.88	.31	1.13	1.29	2.73	.37	.44	.32	------	100.97	------	------
284022	B_1	16–32	[a]69.52	.65	5.92	14.06	.03	.70	1.20	2.38	.97	.09	.05	4.33	99.95	.053	------
			[b]72.68	.68	6.19	14.70	.08	.73	1.25	2.49	1.01	.09	.05	------	99.93	------	------
			[c]47.53	.59	12.45	25.15	.14	.70	2.40	2.71	.07	.22	.10	8.44	100.50	------	------
			[d]51.91	.64	13.49	27.47	.15	.76	2.60	2.96	.08	.23	.11	------	100.40	------	------
284023	B_2	32–36	[a]65.64	.60	5.60	14.73	.13	1.57	1.97	2.64	1.39	.12	.05	5.61	100.05	.069	------
			[b]69.52	.64	5.93	15.61	.14	1.56	2.09	2.80	1.47	.13	.05	------	100.05	------	------
284024	C	36+	[a]47.93	.39	3.34	8.56	.07	13.59	6.05	1.93	.85	.09	.05	17.33	100.18	.029	15.00
			[b]57.97	.47	4.04	10.36	.08	16.43	7.32	2.33	1.03	.11	.06	------	100.22	------	------
			[c]47.13	.60	11.45	24.25	.09	1.50	3.09	4.28	.16	.21	.12	7.23	100.11	------	------
			[d]50.80	.64	12.34	26.14	.10	1.61	3.31	4.59	.17	.22	.13	------	100.05	------	------

[1] Collected by W. E. Tharp. [2] Analyzed by G. Edgington.

TABLE 38.—*Composition of Miami silt loam, Greenfield, Hancock County, Ind.*—Continued

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
284018	A_1	0– 2	1.3	4.4	2.6	12.7	11.2	51.7	16.6	100.5
284019	A_2	2– 5	1.9	2.7	2.4	14.1	13.9	47.9	17.5	100.4
284020	A_3	5–12	.7	2.8	2.6	15.2	12.2	50.4	16.5	100.4
284022	B_1	16–32	.9	3.4	2.7	15.8	14.6	34.5	28.6	100.5
284023	B_2	32–36	1.2	3.1	2.6	15.7	16.8	33.4	27.6	100.4
284024	C	36+	2.6	5.2	3.2	17.8	17.8	37.2	16.4	100.2

[3] Analyzed by J. B. Spencer.

The Podzolic profile is clearly shown in the composition of the several horizons. The percentage of silica in A_2 is about 12 per cent higher than in B, and that in the parent material, below 36 inches, is only about 70 per cent of that in A_2. The percentage of iron oxide ranges from 3.24 in A_2 to 6.19 in B_1 and 4.04 in C. Alumina ranges from 10 in A_2 to 15.6 in B_2 and is 10.36 in C. The CaO in A_1 is nearly 50 per cent higher than in A_2 while in the parent material it is 16.4 per cent, most of which is carbonate, the percentage of the latter being about 30. Potash percentage is highest in B_2, 2.8, while in A_2 it is 2.14, the range not being great. The percentage of soda ranges from 1.01 in B_1 to 1.47 in B_2, and is 1.19 in A_1, the low percentage in B_2 being noticeable. Percentages of P_2O_5 and SO_3 are highest in A_1, the concentration of SO_3 in this layer being marked.

The ratios for the A_2, B_1, and C horizons, horizon A_2 including the value computed from those of both A_2 and A_3, and the molecular equivalent composition are shown in Table 39.

TABLE 39.—*Miami silt loam, Hancock County, Ind.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
284020	A_2	2–12	13.27	64.62	0.532	1.362	0.020	0.98	0.0517
284022	B_1	16–32	8.4	31.11	.387	1.205	.038	1.44	.0557
284024	C	36+	9.5	37.90	3.296	.9613	.025	1.01	.3337

The sa ratios show a rather well-defined accumulation of alumina in the B_1 horizon over that in the C but a much more definite loss in A_2 than gain in B_1. It is apparent that translocation into the B_1 horizon from the A_2 has been much less than the removal from A_2 to the drainage waters or elsewhere. In the case of iron oxide (sf) the ratios are relatively about the same as for alumina.

The molecular equivalent composition shows about 25 per cent more silica molecules in the B_1 horizon than in the C. The low number in the C is due mainly to the high percentage of lime in the latter. This will affect all the substances, however, but the number of molecules of iron oxide in the B_1 horizon is a little more than 50 per cent greater than in C, and of alumina the B_1 horizon has 40 per cent more. The number of alumina molecules in A_2, however, is practically the same as in C, but the number of molecules of iron oxide in A_2 is lower than in C and much lower than in B_1.

The loss of alkalies and alkaline earths from both A_2 and B has been important, but the number of molecules in A is only one-fourth that in B.

The development of the horizons in a well-collected sample of Miami silt loam from Wayne County, Ind., seems somewhat more definite than in the Hancock County profile. The chemical and mechanical composition are shown in Table 40.

TABLE 40.—*Composition of Miami silt loam, Wayne County, Ind.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
283702	A_1	3– 5	[a]80.46	0.72	3.00	7.79	0.04	0.83	0.49	1.64	1.04	0.08	0.12	3.62	99.83	0.100	------
			[b]83.49	.75	3.11	8.09	.04	.86	.51	1.70	1.08	.08	.12	------	99.83	------	------
283703	A_2	6– 9	[a]81.58	.59	2.64	8.21	.05	.49	.30	1.79	1.14	.03	.04	2.90	99.76	.042	------
			[b]84.00	.61	2.72	8.45	.05	.50	.31	1.84	1.17	.03	.04	------	99.72	------	------
283704	B_1	10–15	[a]75.37	.62	4.65	11.41	.04	.51	.72	2.21	1.02	.02	.02	3.43	100.02	.032	------
			[b]78.02	.64	4.78	11.82	.04	.53	.75	2.29	1.06	.02	.02	------	99.97	------	------
283705	B_2	16–30	[a]69.81	.56	6.18	13.72	.03	.72	1.11	2.48	1.11	.07	.03	4.21	100.03	.038	------
			[b]72.89	.57	6.48	14.33	.03	.75	1.16	2.59	1.16	.07	.03	------	100.03	------	------
382706	C_1	31–42	[a]58.92	.37	3.66	9.70	.03	7.40	4.92	1.91	1.12	.08	.03	11.95	100.09	.028	9.42
			[b]66.91	.42	4.16	11.02	.04	8.40	5.59	2.17	1.27	.09	.03	------	100.10	------	------
383707	C_2	43–60	[a]39.24	.21	2.08	5.77	.05	18.93	7.99	1.36	.99	.05	.03	23.44	100.14	.031	22.41
			[b]51.25	.27	2.72	7.54	.06	24.71	10.44	1.78	1.29	.07	.04	------	100.17	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
283702	A_1	3– 5	1.6	3.8	3.0	18.0	17.9	44.8	10.9	100.0
283703	A_2	6– 9	.9	3.2	3.2	19.2	19.6	40.9	13.1	100.1
283704	B_1	10–15	.6	2.9	2.8	16.6	17.5	36.3	23.4	100.1
283705	B_2	16–30	.8	3.6	3.7	20.0	14.8	25.5	31.2	99.6
283706	C_1	31–42	1.4	5.8	5.8	25.8	14.7	28.4	18.5	100.4
283707	C_2	43–60	4.8	9.2	5.2	22.6	18.0	29.3	11.5	100.6

[1] Collected by E. D. Fowler and T. M. Bushnell.
[2] Analyzed by G. J. Hough and G. Edgington.
[3] Analyzed by J. B. Spencer and V. Jacquot.

Silica percentages in the various horizons and subhorizons range between 51 and 84. The lowest percentage is in horizon C and the highest in A_2. When the high percentage of calcium and magnesium carbonates have been calculated out, reducing the percentages of CaO and MgO to about what they are in the solum horizons, the percentage of silica in horizon C is a little less than 80, practically the same as in B_1. The percentage of alumina in B_2 is 14, that in A_1 and A_2 a little above 8, and that in C is 7.5. When the excess of CaO and MgO in C has been calculated out, the percentage of alumina in C stands at 11.5. There is, therefore, an apparent accumulation of alumina in B_2, the percentage in B_1 showing a very small apparent accumulation while that in A_2 shows considerable apparent loss. The percentage of iron oxide in C after calculating out the excess of CaO and MgO is a little above 4, showing an apparent well-defined accumulation in B_2, a small accumulation in B_1, and loss in A_2. The percentages of alkalies are not unusual in any way, while those of the alkaline earths show high percentages in the parent glacial drift, horizon C.

The ratios and molecular equivalent composition for this soil are shown in Table 41.

TABLE 41.—*Miami silt loam, Wayne County, Ind.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
283703	A_2	6– 9	16.90	81.8	0.572	1.400	0.017	0.082	0.0472
283705	B_2	16–30	8.60	29.8	.424	1.214	.040	.140	.0595
283707	C_2	43–60	11.55	49.9	6.531	.853	.017	.074	.4802

The much smaller sa ratio in horizon B_2 than in A_2 or C_2 shows clearly an accumulation of alumina in the first-mentioned horizon. The parent material is glacial drift, and with no evidence to the contrary at hand it must be assumed that the solum of the existing soil was derived from material closely similar to, if not identical with, that in C_2. The drift is highly calcareous, having had its source largely in limestones. It contains presumably a very small percentage of feldspathic minerals. The accumulation of alumina in B_2, therefore, must have been brought about mainly by translocation from above. The high ratio in A_2 shows that relative to silica there is only half as much alumina in that horizon as in B_2. This soil has developed from material accumulated at so late a geological date that extremely little lowering of the surface by erosion has taken place. The percentage of sand in the surface soil has not been increased to an appreciable extent, therefore, by severe erosion, leaving the coarser material behind. Some of the clay in A_2 has been removed by being washed out of the sand, and to this is probably due the higher silica and lower alumina in A_2.

The significantly lower ratio in B_2 than in C_2 shows that the lower ratio in B_2 than in A_2 is due not merely to the removal of alumina from A_2 but also to its accumulation in B_2.

The same relationships among the horizons are shown by the molecular ratios. The difference in sf ratios between B_2 and C_2 is nearly seven times as great as that in the sa ratios. There has been a greater accumulation of iron oxide in B_2 than of alumina. This greater accumulation is reflected also in the great difference of sf ratios between A_2 and B_2. This is in line with what has been shown in most of the other profiles of Gray-Brown Podzolic soils, namely that shifting of iron oxide has taken place to a greater extent in these soils than that of alumina.

The complete analysis shows a very slightly higher percentage of organic matter (N) in B_2 than in B_1. The difference is very small and lies well within the range of possible analytical error, but field examination shows the presence of a faint dark-colored coating on the outsides of soil particles in B_2. It is possible that this may have had some influence in the precipitation of alumina in B_2.

The very high percentage of calcium carbonate in C_2 causes the wide differences in ba ratios. The low ratio in B_2 shows that the alumina in that horizon is less rich in bases than that in A_2. It is not necessary to conclude that there is any actual difference in the kind of compounds of alumina in the two, but the higher ratio in A_2 can be due to the presence of feldspar fragments but not to the presence of bases combined with organic colloids.

The molecular equivalent composition shows that the number of molecules of alumina in A_2 and C_2 per unit weight of material is not very different, the number in A_2 being a little larger. The number in B_2 is nearly twice that in C_2. The number of iron oxide molecules in A_2 and C_2 is the same, but the number in B_2 is twice as great.

The total number of molecules of alkalies and alkaline earths not including magnesia, per unit of weight, is smaller than in B_2, failing to confirm the suggestion of the higher ba ratio in A_2 than in B_2.

Colloid material was extracted from the combined A_2 and A_3 horizons, and from the B_1 and C horizons of the Hancock County, Ind., profile by Holmes and Edgington (*10*) and subjected to complete chemical analysis. The ratios for the several horizons and the molecular equivalent composition are shown in Table 42.

TABLE 42.—*Colloid from Miami silt loam, Hancock County, Ind.*

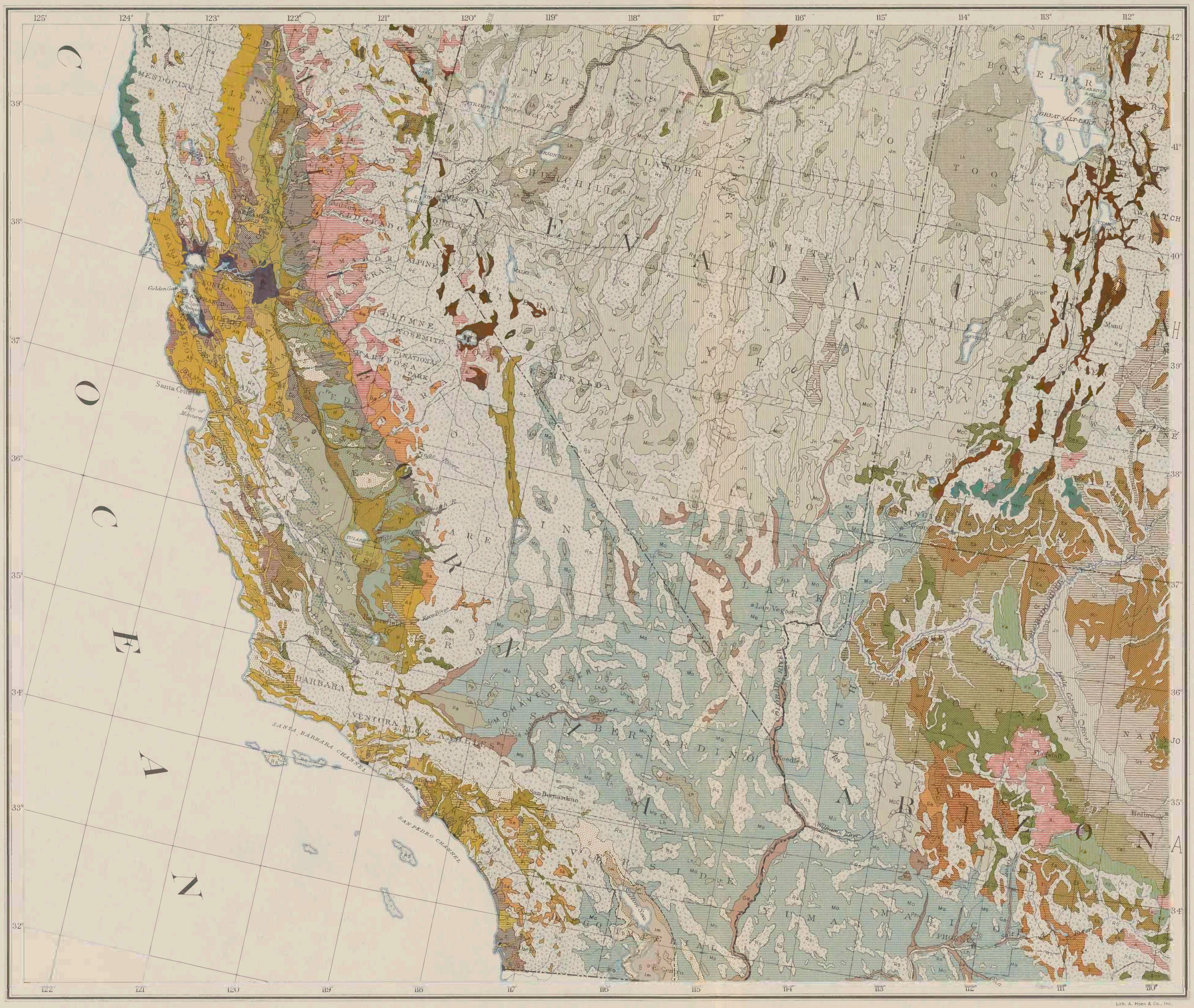
Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
284020	A	2–12	2.93	12.72	0.176	0.867	0.068	0.302	0.0565
284022	B_1	16–32	3.24	10.16	.172	.860	.084	.268	.0457
284024	C	36+	3.30	10.91	.313	.842	.077	.255	.0816

The chemical and mechanical composition of a sample of Miami silty clay loam from Madison County, Ohio, are shown in Table 43 and analyses of the silt loam from Decatur County, Ind., are shown in Table 44. They are normally developed Miami soils, show the usual chemical and physical features of the profile, and need no further discussion.

TABLE 43.—*Composition of Miami silty clay loam, Fayette, Madison County, Ohio*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
272302	A_1	3– 4	[a]78.19	0.79	3.33	9.07	0.09	0.77	0.59	2.09	1.09	0.12	0.11	4.08	100.32	0.120	------
			[b]81.50	.82	3.47	9.47	.09	.80	.62	2.18	1.14	.13	.11	------	100.33	------	------
272303-5	A_2	5–14	[a]75.65	.91	4.08	10.59	.07	.82	.68	2.18	.94	.11	.09	3.81	99.93	.080	------
			[b]78.68	.95	4.24	11.01	.07	.85	.71	2.27	.98	.11	.09	------	99.96	------	------
272306-8	B	15–28	[a]59.37	.77	7.08	14.81	.07	2.92	2.56	2.48	.83	.15	.11	8.55	99.70	.080	2.03
			[b]64.93	.84	7.74	16.18	.08	3.19	2.80	2.71	.91	.16	.12	------	99.67	------	------
272309	C	29–35	[a]50.94	.64	5.46	12.78	.06	7.45	5.10	2.33	.64	.13	.11	14.00	99.64	.080	9.03
			[b]59.26	.74	6.35	14.86	.07	8.66	5.93	2.71	.74	.15	.13	------	99.60	------	------

[1] Collected by A. E. Taylor. [2] Analyzed by G. J. Hough.



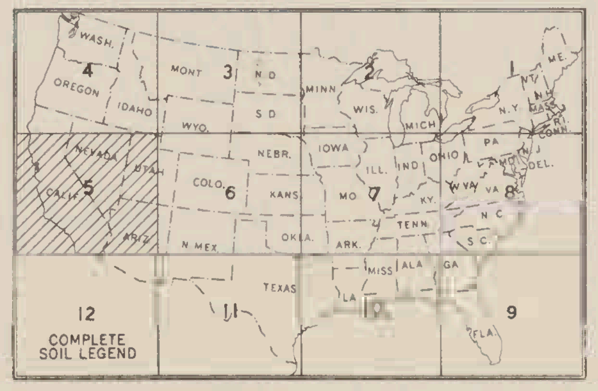
LEGEND FOR THIS SECTION

Aiken	Gila	Meeker	Sierra
Altamont	Hanford	Melbourne	Stockton
Antioch	Humboldt	Mohave	Trenton
Capay	Hyrum	Otero	Yolo
Coronado	Imperial	Panoche	Valera
Deschutes	Jordan	Placentia	Willamette
Dublin	Kaibab	Pond	Willows
Elgin	Kettleman	Ritzville	Marsh and Swamp
Encina	Lahontan	Sacramento	Peat and Muck
Fresno	McCammon	San Joaquin	Sand
Laurel	Portsmouth	Rough and Stony land	light Bad land

Highly developed orchard region on Holland, Sierra, and Aiken soils, near Auburn, Placer County, Calif.

Desert vegetation on the Mohave soils in southeastern California. The taller plants are Covillea (creosote bush)

ARRANGEMENT OF SECTIONS

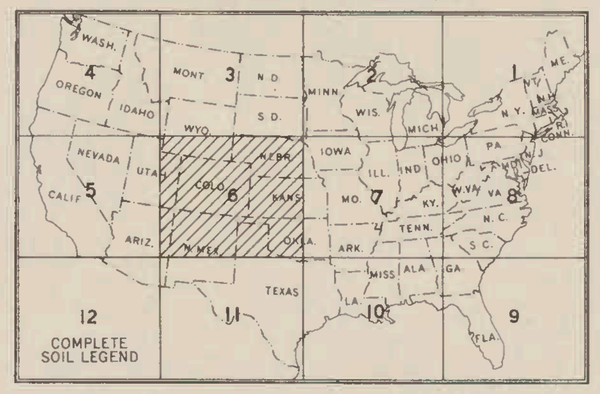


LEGEND FOR THIS SECTION

Abilene	Deschutes	Meeker	Sierra
Aiken	Encina	Melbourne	Springer
Altamont	Everett	Miller	Springer sand
Amarillo	Gila	Moody	Summit
Amarillo sand	Hall	Onyx	Susquehanna
Bates	Hanceville	Otero	Trenton
Barnes	Hays	Parsons	Valentine
Carrington	Holdrege	Phillips	Vernon
Colby	Jordan	Pierre	Wabash
Crawford	Kirkland	Reagon	Waukesha
Crete	Knox	Reeves	Windthorst
Daniels	Lahonton	Rosebud	Bad land
Dawes	Laurel	Scott	Marsh and Swamp
Derby	McCammon	Shelby	Sand
Valera	Manor	Sioux	light Rough and Stony land

Profile of a soil near Vaughn, Guadalupe County, N. Mex., showing the thin surface soil, weathered from indurated carbonate, and a thick underlying layer (the indurated carbonate zone)

ARRANGEMENT OF SECTIONS



Lith. A. Hoen & Co., Inc.

TABLE 43.—*Composition of Miami silty clay loam, Fayette, Madison County, Ohio*—Continued

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
272302	A_1	3–4	0.3	1.4	0.9	5.7	11.7	60.5	19.6	100.1
272303–5	A_2	5–14	.3	1.1	.9	5.0	10.9	57.0	24.8	100.0
272306–8	B	15–28	.7	1.4	.9	5.9	11.3	41.7	38.4	100.3
272309	C	29–35	3.4	12.4	7.1	25.4	11.8	25.4	14.6	100.1

3 Analyzed by J. B. Spencer and V. Jacquot.

TABLE 44.—*Composition of Miami silt loam, Westport, Decatur County, Ind.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28526	A_1	0–¾	[a]71.96	1.00	2.71	7.16	0.10	1.41	0.57	1.38	0.60	0.28	0.26	11.75	99.18	0.430	------
			[b]81.40	1.14	3.07	8.10	.11	1.61	.65	1.58	.69	.32	.30	------	100.01		
28527	A_2	¾–10	[a]78.55	.79	2.77	9.32	.08	.72	.60	1.93	.79	.18	.13	4.00	99.86	.170	------
			[b]81.80	.82	2.89	9.72	.08	.75	.63	2.01	.82	.19	.14	------	100.01		
28528	B	10–33	[a]72.31	.69	4.57	12.86	.10	1.11	1.03	2.03	.96	.19	.09	3.57	99.51	.060	------
			[b]74.90	.72	4.76	13.41	.10	1.16	1.07	2.11	1.00	.20	.09	------	100.01		
28529	C	34–42	[a]66.26	.65	5.06	11.52	.08	4.15	2.72	2.13	1.23	.32	.15	5.69	99.96	.050	------
			[b]70.30	.69	5.37	12.23	.08	4.40	2.89	2.26	1.30	.34	.16	------	100.02		

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28526	A_1	0–¾	0.8	4.0	2.0	8.2	6.5	63.4	15.1	100.0
28527	A_2	¾–10	.7	2.6	1.8	6.9	9.0	61.2	18.0	100.2
28528	B	10–33	1.0	2.4	2.6	15.3	9.8	25.0	43.4	100.0
28529	C	34–42	1.0	3.8	4.0	24.8	8.8	34.0	23.5	99.9

1 Collected by C. F. Marbut.
2 Analyzed in the division of soil chemistry, Bureau of Soils, Mar. 20, 1920.
3 Analyzed by A. A. White.

A sample of colloid was extracted from the B horizon of Miami silty clay loam from Jefferson, Wells County, Ind., by Robinson and Holmes (*15*). Since the parent material was not sampled the results have very little value in this discussion. The alumina-silica (sa) ratio, however, 3.4, is high as is usual in Miami soils.

The Crosby soils are very closely related to the Miami, being developed from the same parent material but on areas of smooth relief and under the influence of rather high ground water. The profile consists, from the surface downward, of a thin dark-gray layer, a gray or nearly white layer, a brown heavier layer, and the parent material.

Material from a profile of Crosby silt loam, from Wayne County, Ind., was carefully sampled and subjected to complete (fusion) chemical analysis. The results of this and also the mechanical composition are given in Table 45.

TABLE 45.—*Composition of Crosby silt loam, Wayne County, Ind.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
283758	A_1	0–3	[a]76.11	0.67	2.75	8.47	0.15	0.95	0.15	1.80	1.17	0.16	0.09	7.81	100.28	0.262	------
			[b]82.58	.73	2.98	9.19	.16	1.03	.16	1.95	1.27	.17	.10	------	100.32	------	------
283759	A_2	4–5	[a]77.90	.79	3.58	8.65	.24	.85	.52	1.79	1.05	.13	.11	4.25	99.86	.120	------
			[b]81.32	.83	3.74	9.04	.25	.89	.54	1.87	1.10	.14	.11	------	99.83	------	------
283760	A_3	6–10	[a]75.26	.81	5.47	9.22	.81	.79	.76	1.82	1.02	.10	.05	4.03	100.14	.060	------
			[b]78.39	.84	5.70	9.65	.84	.82	.79	1.90	1.06	.10	.05	------	100.14	------	------
283761	A_4	11–18	[a]75.38	.81	4.62	11.33	.15	.80	.75	1.82	.89	.07	.03	4.15	100.80	.040	------
			[b]78.65	.85	4.82	11.82	.16	.83	.78	1.90	.93	.07	.03	------	100.84	------	------
283762	B_1	19–26	[a]68.82	.74	5.12	14.51	.08	1.07	1.27	1.84	.93	.08	.04	5.30	99.80	.040	------
			[b]72.67	.77	5.41	15.32	.08	1.13	1.34	1.94	.98	.08	.04	------	99.76	------	------
283763	B_2	27–28	[a]71.91	.54	5.17	12.15	.08	1.68	1.42	1.99	1.15	.15	.02	3.90	100.16	.030	------
			[b]74.85	.56	5.38	12.64	.08	1.75	1.48	2.07	1.20	.16	.02	------	100.19	------	------
283764	C	29–60	[a]49.34	.38	3.15	7.56	.07	13.50	5.80	1.51	1.01	.10	.04	17.70	100.16	.020	16.35
			[b]59.94	.46	3.83	9.19	.09	16.41	7.05	1.83	1.23	.12	.05	------	100.20	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
283758	A_1	0–3	0.8	3.0	1.9	8.2	9.4	61.4	15.2	99.9
283759	A_2	4–5	1.7	2.8	1.9	7.6	12.2	60.0	13.6	99.8
283760	A_3	6–10	11.0	5.1	1.9	6.9	11.3	51.4	12.3	99.9
283761	A_4	11–18	3.6	3.3	1.0	4.5	34.4	49.1	16.5	100.1
283762	B_1	19–26	1.2	1.5	1.2	8.0	22.8	58.2	14.0	99.9
283763	B_2	27–28	3.2	5.7	4.8	24.0	19.7	30.1	12.5	100.0
283764	C	29–60	4.2	6.8	4.2	20.0	22.2	29.9	12.5	99.8

1 Collected by E. D. Fowler and T. M. Bushnell.
2 Analyzed by G. Edgington and G. J. Hough.
3 Analyzed by A. A. White.

In this profile the A horizon was broken into four layers on the basis of slight differences in color or structure and the B horizon into two. The A_2 horizon extends from 4 to 18 inches. The lower layer of the A_2 horizon, designated in the table as A_4, has a lower percentage of iron oxide but a higher percentage of alumina than the higher layers. The mechanical composition shows about 30 per cent more clay in the A_4 layer than in the one above it. The relatively high percentage of clay in A_1 is mainly due to the presence of organic matter.

The percentage of alumina in B_1 is 70 per cent higher than the lowest percentage in any of the layers of A. This is almost exactly the same ratio as that between the highest percentages of alumina in any part of the B horizon and the lowest in any part of the A in both profiles of Miami silt loam previously discussed. The apparent increase of iron oxide in the B horizon over the lowest in any part of A is about 75 per cent. In the Wayne County Miami silt loam the apparent increase is nearly twice this and in the Hancock County profile of the same soil the apparent increase is about 90 per cent. In chemical composition, therefore, the Crosby soils do not differ greatly from the Miami soils. The difference lies mainly in the physical features of the several horizons, described on page 27. Crosby silt loam is an eluviated soil and in texture and general chemical composition is a member of the Gray-Brown Podzolic soils.

The ratios for the several horizons and the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 46.

TABLE 46.—*Crosby silt loam, Wayne County, Ind.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
283758	A_1	0–3	15.28	73.44	0.662	1.370	0.0186	0.090
283759 283760 283761	A_2 A_3 A_4	4–18	12.31	41.52	.479	1.310	.0315	.1067
283762	B_1	19–26	8.06	35.59	.364	1.210	.0340	.1500
283764	C	29–60	11.08	41.34	3.690	.999	.0240	.0900

The sa ratio for horizon B_1 is much lower than that for C. Since presumably there was no difference in composition in the parent rock between the material in the zone converted into horizon B and that now constituting horizon C, and since also the original material had a very low percentage of feldspathic minerals the lower ratio in B_1 must signify an actual transfer of alumina into this horizon from elsewhere. The high ratio in A_1 is that of a layer of rather sandy material accumulated as a residual accumulation by the removal by water of the finer material. Part of this has probably been washed into B_1 by percolating water and part removed entirely from the soil.

The sf ratios show less difference between horizons C and B_1 than the sa ratios. That of the B_1 horizon is lower than that in C by 12 per cent, while the sa ratio in B_1 is lower than that in C by nearly 30 per cent. The ratios in the lower divisions of horizon A are almost exactly the same as in C. The sa ratio in these lower parts of horizon A is also nearly the same as that in C. It appears that alumina has suffered more from eluviation in this soil than has iron oxide.

The molecular equivalent composition shows essentially the same relationships as the several ratios. The relative number of molecules of alumina per unit of weight in B_1 is high, that in the other horizons, including C, is low. The same may be said of iron oxide, but the reverse is true of silica.

The Bethel soils occupy situations practically identical with those of the Crosby series. They differ from the latter in being less well drained. The middle part of the A horizon is nearly white, the lower part mottled with soft iron oxide spots, as is also the B horizon.

The composition of material from a profile of Bethel silt loam in Hancock County Ind., is shown in Table 47.

TABLE 47.—*Composition of Bethel silt loam, Westland, Hancock County, Ind.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
284025	A_1	0–5	[a]75.71	0.72	2.95	9.13	0.14	0.75	0.60	2.07	1.28	0.14	0.11	6.76	100.36	0.231	------
			[b]81.19	.77	3.16	9.79	.15	.80	.64	2.22	1.37	.15	.12	------	100.36	------	------
284026	A_2	5–10	[a]78.35	.72	3.21	9.70	.13	.57	.62	2.13	1.18	.05	.05	3.55	100.26	.076	------
			[b]81.26	.75	3.33	10.06	.14	.59	.64	2.21	1.22	.05	.05	------	100.30	------	------
284027	A_3	10–15	[a]72.58	.74	5.00	12.64	.07	.68	1.04	2.32	1.13	.05	.05	4.05	100.35	.054	------
			[b]75.60	.77	5.21	13.17	.08	.71	1.08	2.42	1.18	.05	.05	------	100.32	------	------
284028	B	15–22	[a]65.25	.68	6.20	16.22	.15	1.09	1.68	2.70	1.31	.07	.02	5.03	100.40	.057	------
			[b]68.69	.72	6.53	17.08	.15	1.15	1.77	2.84	1.38	.07	.02	------	100.40	------	------
284029	C	22–24	[a]55.67	.59	5.25	13.62	.09	6.12	4.45	2.68	1.14	.12	.02	10.56	100.31	.037	6.88
			[b]62.26	.66	5.87	15.23	.10	6.84	4.98	3.00	1.27	.13	.02	------	100.36	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
284025	A_1	0–5	1.5	3.1	1.9	7.4	10.0	62.8	13.5	100.2
284026	A_2	5–10	.5	1.8	1.4	6.6	13.1	60.1	16.5	100.0
284027	A_3	10–15	.4	1.5	1.2	6.0	10.0	55.0	25.7	99.8
284028	B	15–22	.6	1.5	1.4	8.5	16.4	39.5	32.1	100.0
284029	C	22–24	1.1	1.8	1.4	10.2	15.6	38.5	31.5	100.1

1 Collected by W. E. Tharp.
2 Analyzed by G. Edgington.
3 Analyzed by J. B. Spencer.

The percentages of alumina in A_1, A_2, and B are almost the same as in the corresponding horizons of the Crosby sample, the apparent accumulation of alumina being a little greater. The same statement is essentially true of iron oxide and silica. The depth to parent material in the Bethel soil is a little less than in the Crosby, probably due both to the presence of ground water and a somewhat greater accumulation of alumina in B. There is a slight difference shown by the mechanical composition table in clay content between horizons B and C but a much greater difference between A_1 and B.

An apparent increase of alumina has taken place in horizon B, but the percentage in B is only about 45 per cent higher than the lowest in any layer of A instead of 70 as in the Crosby profile from Wayne County and is only 10 per cent higher than in horizon C. The percentage of iron oxide in B is 50 per cent higher than the lowest in any layer of horizon A. In the Wayne County sample this higher percentage is 75 instead of 50, but the percentage in B is only about 10 per cent higher than in C. The complete chemical analysis indicates a slight accumulation of both iron oxide and alumina in B compared with C, but the loss from horizon A has been important.

The ratios and molecular equivalent composition of Bethel silt loam, Hancock County, Ind., are shown in Table 48.

TABLE 48.—*Bethel silt loam, Westland, Hancock County, Ind.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
284025	A_1	0–5	14.10	68.09	0.625	1.346	0.0198	0.0958
284026	A_2	5–10	13.70	64.66	.545	1.347	.0208	.0985
284028	B	15–22	6.83	27.87	.430	1.139	.0409	.1671
284029	C	22–24	6.95	28.10	1.169	1.032	.0367	.1490

The sa ratios show that very little change in soil building has taken place between horizon B and the parent material in C. There is also very little difference in the silica-alumina ratio between A_1 and A_2, but both are widely different from B as well as from C. Assuming that the actual loss of silica in the course of soil development has been small, an assumption not wholly unreasonable where development has taken place in calcareous glacial till, the loss of alumina from A_1 and A_2 has been about half the total amount present in the parent material. This has disappeared from the soil profile, whereas in the Miami profiles developed under good drainage an important part of the alumina lost from A has been accumulated in B.

The sf ratios tell essentially the same story as the sa ratios. A slight accumulation seems to have taken place in A_1 above that in A_2. The loss of bases has of course been heavy since the parent glacial drift contains about 7 per cent of CaO, most of which is carbonate. Ratios between potash alone and alumina in A_2 and B of 22 and 16, respectively, show that the higher percentage of alumina in B does not maintain an equally high percentage of potash, compared with A_2.

On account of the presence of a high percentage of calcium carbonate in C the relative number of molecules, per unit of weight, of all other constituents in this horizon must be low. When, however, the excess of CaO over that in the other horizons has been calculated out the molecular equivalent composition tells the same story as the ratios. Iron oxide and alumina have been lost from the layers of horizon A, but practically none of this has been saved to the profile by being deposited in B.

It has already been stated that the Clinton soils are close relatives of the Miami. They are not only members of the Gray-Brown Podzolic group but have a profile morphologically like that of the Miami. They have developed from calcareous, presumably wind-blown, silts.

The chemical and mechanical composition of material from a profile of Clinton silt loam from Jones County, Iowa, are shown in Table 49. The mechanical composition shows a relatively high content of clay between depths of 20 and 50 inches and a lower content below that; that of silt is lowest in the 20 to 50 inch depth and highest in the parent material but high also in the surface soil.

TABLE 49.—*Composition of Clinton silt loam, Amber, Jones County, Iowa* [1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
336424	A_1	0–12	[a] 79.57	0.63	2.34	8.86	0.20	0.75	0.61	2.03	1.48	0.07	0.05	3.70	100.29	0.101	------
			[b] 82.62	.65	2.43	9.20	.21	.78	.63	2.11	1.54	.07	.05	------	100.29	------	------
336425	A_2	12–20	[a] 78.97	.64	2.82	9.99	.17	.60	.73	2.14	1.42	.06	.05	2.91	100.50	.054	------
			[b] 81.32	.66	2.90	10.29	.17	.62	.75	2.20	1.46	.06	.05	------	100.48	------	------
336426	B	20–50	[a] 74.39	.59	4.54	12.24	.12	.67	1.03	2.03	1.23	.10	.04	3.45	100.43	.031	------
			[b] 77.06	.61	4.70	12.68	.12	.69	1.07	2.10	1.27	.10	.04	------	100.44	------	------
336427	C	50+	[a] 66.92	.50	2.86	9.27	.04	6.10	3.10	1.81	1.47	.15	.03	7.95	100.20	.005	6.28
			[b] 72.70	.54	3.11	10.07	.05	6.62	3.36	1.97	1.60	.16	.03	------	100.21	------	------

Sampie No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
336424	A_1	0–12	0.0	0.5	0.4	2.8	20.5	62.1	13.0	99.3
336425	A_2	12–20	.6	3.2	1.7	5.4	21.2	56.1	11.6	99.8
336426	B	20–50	.2	1.2	.9	4.9	24.4	52.2	16.3	100.1
336427	C	50+	.0	.0	.0	2.0	24.6	63.4	10.0	100.0

[1] Collected by R. E. Devereux.
Analyzed by G. Edgington.
Analyzed by V. Jacquot.

The relative percentages of silica, iron oxide, and alumina in the several horizons are those characteristic of Podzolic soils. The percentages of alumina and iron oxide in B (20 to 50 inches) are higher than those of the same constituents in the layers of horizon A or of horizon C.

Part of the low percentages of both these constituents as well as of all others except calcium oxide is due to the high percentage of calcium oxide present. When this excess, however, above that in the other horizons has been calculated out, the percentages of alumina and iron oxide are still lower than in B, showing apparent accumulation of these constituents. The percentages of alkalies and alkaline earths, except for the high carbonates of calcium and magnesium in C and their influence on the other constituents, are strikingly uniform throughout the profile.

The various ratios and molecular equivalent composition in SiO_2, Fe_2O_3 and Al_2O_3 are shown in Table 50.

TABLE 50.—*Clinton silt loam, Amber, Jones County, Iowa*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
336425	A_2	12–20	13.43	74.31	0.575	1.348	0.0181	0.1006
336426	B	20–50	10.33	43.45	.443	1.277	.0291	.1240
336427	C	50+	12.27	61.94	1.671	1.205	.0194	.0975

The sa ratios are low, as usual in Podzolic soils, in horizon B and high in A_2 and C, but the difference between those for B and C is, as usual also, less than that between A_2 and B, suggesting at least if not proving that there has been more alumina removed from A_2 than has been accumulated in B. Without volume weight determinations and careful computations on that basis with carefully measured thicknesses of the horizons this can not be considered proved, but it is suggested.

The sf ratio in B is lower than in A_2 and C also, but the differences from both A_2 and C are greater than the sa differences. The difference between the sf ratio in B and that in C is smaller than that between the same ratios in B and A_2 as in the sa ratios. There has been in iron oxide also seemingly a greater amount removed from A_2 than has accumulated in B.

Alkalies and alkaline earths have been removed from both A_2 and B, but the amount in A_2 relative to alumina is greater than in B. This is probably owing to the presence of bases in A_2 combined with organic matter. It may also be due in part to the greater richness in bases of the clays or silts in A_2 than in B.

The molecular equivalent composition shows a smaller number of silica molecules in C per unit weight than in B, but when the excess of CaO and MgO over the percentages of these constituents in the other horizons has been calculated out, the number in C stands almost exactly the same as in B.

The soils developed from sandstones and shales in central Kentucky and central Indiana are members mainly of the Muskingum series. These sandstones and shales are Paleozoic in age and are coal bearing, being essentially a westward reappearance of the carboniferous sandstones and shales of the Allegheny Plateau west of the interruption known as the Cincinnati anticline. Like the Allegheny Plateau this region, although much lower, is mainly thoroughly dissected. There are, however, small remnants still undissected by the invasion of existing cycle streams. Some of these areas lie in Indiana, others in Kentucky.

The soils on them are better developed than the Muskingum occurring on the steep slopes of the dissected areas, but they have been influenced somewhat, it seems, by ground water. These soils, up to the present time, have been identified as members of the Tilsit series.

No analysis has yet been made of material from a typical Tilsit profile. Table 51 shows the chemical and mechanical composition of material from a profile lying on the border of a Tilsit area in Muhlenberg County, Ky. It does not show the composition of the indurated horizon which is present but shows the composition of the solum and is included in order to make a comparison of the solum in the sandstone and shale derived material with that in limestone derived material in the Miami soils.

TABLE 51.—*Composition of Tilsit silt loam, South Carrollton, Muhlenberg County, Ky.* [1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28534	A	0–2	[a] 81.50	0.95	2.44	7.65	0.06	0.71	0.45	1.75	0.79	0.06	0.13	4.57	101.06	0.110	------
			[b] 85.40	.99	2.56	8.02	.06	.74	.47	1.81	.82	.06	.13	------	101.06	------	------
28535	B_1	2–24	[a] 74.36	1.06	5.30	11.94	.02	.41	.70	2.03	.70	.09	.13	3.67	100.41	.020	------
			[b] 77.20	1.10	5.50	12.39	.02	.43	.73	2.11	.73	.09	.13	------	100.43	------	------
28536	B_2	24–30	[a] 75.50	.90	4.52	11.55	.02	.72	.66	2.15	1.15	.09	.06	2.63	99.95	.010	------
			[b] 77.57	.92	4.64	11.86	.02	.74	.68	2.21	1.18	.09	.06	------	99.97	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28534	A	0–2	4.8	0.6	0.5	1.9	4.9	71.8	15.5	100.0
28535	B_1	2–24	.0	.4	.4	1.1	8.3	62.6	27.3	100.1
28536	B_2	24–30	.4	.8	.6	2.0	8.2	58.1	29.9	100.0

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough.
[3] Analyzed by A. A. White.

The percentage of clay in B is twice that in A, the texture profile being well developed. The percentage of sand is low, practically all sand present being fine and very fine. Silt and clay amount to 87 per cent of the material in horizon A and 88 per cent of that in B_2.

Iron oxide and alumina are higher in B than in A, but since C was not sampled it can not be determined whether or not material has accumulated in B or has merely been removed from A.

The percentages of potash and Na_2O are moderate, phosphorus is low, and CaO is low. Nitrogen, except in the very thin surface layer, is very low. The nitrogen percentage in the several horizons is typical of that in the well-drained normal forest soils of the United States.

The Cincinnati soils, the dominant type being silt loam, are also near relatives of the Miami soils. They have developed from old calcareous glacial drift which has been leached of its free carbonates to a depth of 10 feet or more. In many localities the drift layer is no thicker than the depth of leaching.

The chemical and mechanical composition of material from a profile of Cincinnati silt loam from Clermont County, Ohio, are shown in Table 52. For making the chemical analysis a number of the layers were combined into one sample. The mechanical analysis shows that the A horizon extends to 16 inches, from 16 to 20 inches is a transitional horizon, included in B for chemical analysis, and the B horizon extends from 20 to 32 inches, the layer from 32 to 48 inches being essentially transitional to C. From 48 inches to 10 feet the material consists of glacial drift, decomposed and leached of its carbonates.

The chemical composition shows the usual podzolic features, moderately developed. Like Clinton silt loam, the alkalies and alkaline earths, except calcium, have not been excessively leached. These soils occur on rolling areas and, partly for that reason, the profile is not highly developed. The A horizon has been deprived of part of its iron oxide and alumina, but horizon B has not accumulated a percentage of alumina or of iron oxide higher than those in C. The percentage of clay shown by the mechanical analysis increases progressively downward to about 8 feet. Below that it seems to decrease. The percentage of CaO in the thin A_1 horizon is a little higher than in A_2.

TABLE 52.—*Composition of Cincinnati silt loam, Owenville, Clermont County, Ohio* [1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
272643	A_1	0–2	[a] 76.02	0.86	2.70	9.22	0.18	0.32	0.53	1.68	1.13	0.24	0.42	6.73	100.03	0.204	------
			[b] 81.50	.92	2.89	9.88	.19	.34	.57	1.80	1.21	.26	.45	------	100.01	------	------
272644–6	A_2	2–16	[a] 78.82	.88	2.84	8.96	.19	.28	.47	1.69	1.06	.25	.39	4.70	100.53	.124	------
			[b] 82.70	.98	2.98	9.41	.20	.29	.49	1.78	1.11	.26	.41	------	100.55	------	------
272647–50	B	16–43	[a] 77.04	.72	4.15	10.73	.09	.43	.73	1.58	1.07	.19	.41	3.22	100.36	.036	------
			[b] 79.59	.74	4.29	11.08	.09	.44	.75	1.63	1.10	.20	.42	------	100.34	------	------
272651–3	C	43–120	[a] 66.23	.70	6.93	15.37	.12	.77	1.34	2.36	.99	.49	.08	4.81	100.19	.042	------
			[b] 69.58	.74	7.28	16.15	.12	.81	1.41	2.48	1.04	.51	.08	------	100.20	------	------

[1] Collected by A. E. Taylor.
[2] Analyzed by G. Edgington.

Table 52.—*Composition of Cincinnati silt loam, Owenville, Clermont County, Ohio*—Continued

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
272643	A_1	0- 2	0.1	0.4	0.2	0.4	2.9	78.8	17.0	99.8
272644-6	A_2	2- 16	.5	.5	.3	1.6	6.6	73.7	16.8	100.0
272647-50	B	16- 48	.8	1.5	1.0	5.0	9.3	59.7	22.5	99.8
272651-3	C	48-120	.8	2.7	1.4	8.0	11.6	38.6	37.7	100.8

[3] Analyzed by A. A. White.

Shelbyville soils are shown on the map as Lowell. They occur in central Kentucky. One set of profile samples has been analyzed, the results being shown in Table 53. The C horizon was not reached in sampling. These soils are derived from shaly limestones. The Podzolic profile is not well developed. The percentage of phosphoric acid is high, and in future work these soils may be identified as Maury, this being the name given to soils developing a Gray-Brown Podzolic profile from limestone beds containing high phosphate, in which the phosphates have not been leached to a low percentage.

Table 53.—*Composition of Shelbyville silt loam, Shelbyville, Ky.*[1]

Sample No.	Horizon	Depth	Chemical [2]													
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
391007	A	0- 6	[a]76.22	1.05	4.39	8.85	0.37	0.94	0.57	1.58	0.58	0.46	0.11	5.41	100.53	0.170	
			[b]80.58	1.11	4.64	9.36	.39	.99	.60	1.67	.61	.49	.12		100.56		
391008	B_1	6-22	[a]74.61	1.20	5.62	10.33	.27	.60	.74	1.73	.57	.50	.08	4.21	100.46	.080	
			[b]77.90	1.25	5.87	10.79	.28	.63	.77	1.81	.60	.52	.08		100.42		
391009	B_2	22-36	[a]71.07	1.09	6.47	11.83	.32	.82	.77	1.73	.50	.77	.07	5.04	100.48	.080	
			[b]74.88	1.11	6.79	12.46	.34	.86	.81	1.82	.53	.81	.07		100.46		

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
391007	A	0- 6	0.1	1.5	1.4	2.2	6.4	74.4	14.1	100.1
391008	B_1	6-22	.2	1.4	1.0	1.6	4.2	66.9	24.7	100.0
391009	B_2	22-36	.2	2.1	1.0	2.0	4.0	60.7	30.0	100.0

[1] Collected by C. Van Duyne.
[2] Analyzed by R. S. Holmes and G. Edgington.
[3] Analyzed by J. W. Bomboy.

COMPOSITION OF CLYDE, BROOKSTON, AND CLERMONT SOILS

All these soils have developed under the influence of excessive moisture and all from calcareous glacial till. They all occur in the Miami region though the Clyde soils extend beyond it. The chemical and mechanical composition of material from a Clyde profile in Wells County, Ind., are shown in Table 54.

Table 54.—*Composition of Clyde silty clay loam, Wells County, Ind.*[1]

Sample No.	Depth	Chemical [2]													
		SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
282207	0- 6	[a]62.85	0.69	4.79	14.12	0.04	1.28	1.28	2.79	0.50	0.41	0.27	10.98	100.00	0.310	
		[b]70.60	.78	5.41	15.86	.05	1.44	1.44	3.14	.56	.46	.30		100.04		
282208	6-16	[a]65.88	.71	5.40	14.42	.05	1.59	1.53	2.68	.71	.33	.21	6.49	100.00	.150	
		[b]70.43	.76	5.78	15.42	.05	1.70	1.64	2.87	.76	.35	.22		99.98		
282209	16-36	[a]67.20	.71	5.33	14.51	.06	1.39	1.69	2.77	.54	.25	.20	5.35	100.00	.090	
		[b]70.99	.75	5.63	15.33	.06	1.47	1.79	2.93	.57	.26	.21		99.99		

Sample No.	Depth	Mechanical [3]							
		Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
	Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
282207	0- 6	0.6	2.0	1.8	9.4	8.9	46.0	31.3	100.0
282208	6-16	.8	2.2	2.0	8.6	8.0	43.8	34.6	100.0
282209	16-36	1.0	2.8	2.0	8.4	7.0	47.7	31.0	99.9

[1] Collected by W. E. Tharp.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, June 19, 1917.
[3] Analyzed by J. W. Bomboy.

The striking fact is the uniformity of the material to a depth of at least 36 inches. The range of all important constituents throughout the profile, including alkalies and alkaline earths, is about one-half of 1 per cent. There is no accumulation of alkalies or alkaline earths in a thin surface horizon like that in the well-drained soils where organic matter is accumulated, since the layer of organic matter in Clyde is thick. The downward percolation of water and consequent leaching of layers below the layer of organic matter in the normal well-drained soils has not taken place in the Clyde, but on the other hand there has been at least an opportunity for enrichment in bases by mineral material, both in solution and suspension, washed in from surrounding areas.

The chemical and mechanical composition of material from a profile of Brookston clay loam, Greensburg, Ind., are shown in Table 55. They show the same relative composition of the several horizons as in the Clyde, the range of silica change between extremes being a little more than 1 per cent, but in none of the other constituents is it so large.

Table 55.—*Composition of Brookston clay loam, Greensburg, Ind.*[1]

Sample No.	Depth	Chemical [2]													
		SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28523	0-10	[a]70.08	0.71	4.05	12.01	0.06	1.24	0.81	1.99	1.17	0.47	0.29	7.12	99.99	0.240	
		[b]75.48	.76	4.31	12.93	.06	1.34	.87	2.14	1.26	.51	.31		99.97		
28524	11-30	[a]73.92	.40	4.31	12.28	.09	1.32	1.01	2.25	1.11	.15	.11	3.22	100.17	.090	
		[b]76.26	.41	4.45	12.66	.09	1.36	1.04	2.32	1.15	.15	.11		100.00		
28525	31-40	[a]72.56	.61	4.77	12.88	.12	1.23	1.05	2.25	1.05	.28	.16	3.03	99.99	.080	
		[b]74.81	.63	4.92	13.28	.12	1.27	1.08	2.32	1.08	.29	.16		99.96		

Sample No.	Depth	Mechanical [3]							
		Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
	Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28523	0-10	0.8	2.3	3.6	7.6	6.2	50.0	29.4	99.9
28524	11-30	.6	1.8	3.0	6.3	5.6	44.3	38.4	100.0
28525	31-40	.3	1.2	2.2	4.8	4.4	44.5	42.5	99.9

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Mar. 20, 1920.
[3] Analyzed by L. T. Alexander.

Brookston soils occur in exactly the same situations as Clyde, in depressions on the plain of ground moraine of the Miami region and in the prairies. They are somewhat lighter in color than the Clyde soils.

Clermont soils have developed on flat areas under the influence of alternating wet and dry conditions. The chemical and mechanical composition of samples from a profile at Millhousen, Ind., are shown in Table 56. The first layer, covering a thickness of half an inch only, is mainly leaf mold.

Table 56.—*Composition of Clermont silt loam, Millhousen, Decatur County, Ind.*[1]

Sample No.	Depth	Chemical [2]													
		SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28530	0-½	[a]73.12	0.60	1.82	3.29	0.24	1.19	0.35	1.23	0.63	0.09	0.20	16.56	99.12	0.560	
		[b]87.61	.72	2.18	3.94	.29	1.43	.42	1.47	.75	.11	.24		99.16		
28531	½-30	[a]85.55	.93	1.59	7.38	.06	.43	1.12	1.12	.92	.10	.12	1.60	100.92	.060	
		[b]86.90	.94	1.62	7.50	.06	.44	1.14	1.14	.93	.10	.12		100.89		
28532	30-40	[a]82.66	.98	2.83	8.28	.04	.44	.48	1.20	.93	.13	.14	2.09	100.20	.040	
		[b]84.42	1.00	2.89	8.46	.04	.45	.49	1.23	.95	.13	.14		100.20		
28533	40-42	[a]76.82	.77	6.52	9.01	.11	.40	.51	1.45	1.69	.39	.10	2.66	100.43	.050	
		[b]78.93	.79	6.70	9.25	.11	.41	.52	1.49	1.74	.40	.10		100.39		

Sample No.	Depth	Mechanical [3]							
		Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
	Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28530	0-½	0.8	3.2	3.9	6.9	4.5	58.8	21.7	99.8
28531	½-30	1.8	2.3	4.2	6.3	4.7	61.5	19.3	100.1
28532	30-40	.9	2.6	3.4	5.4	4.1	53.8	29.7	99.9
28533	40-42	1.4	4.5	4.2	6.4	4.6	47.8	31.1	100.0

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Mar. 20, 1920.
[3] Analyzed by L. T. Alexander.

No podzolic zonation has developed. The lowest layer analyzed is only 3 inches thick and is a little heavier than the layers above, but the difference is slight. The range in composition of alumina is from 7.50 per cent, in the layer extending from one-half inch to 30 inches, within which no differentiation into horizons could be made in the field, to 9.25 per cent, a range of only 1.75 per cent. The percentage of iron oxide in the 40 to 42 inch layer is high owing to ground water influence. Field evidence showed that it had nothing whatever to do with eluviation and ordinary normal podzolic development.

The eastern part of Ohio, the western part of Pennsylvania, most of West Virginia, and the southern part of New York contain soils developed from sandstone and shale materials containing a small limestone constituent in places, accumulated either by residual decay, glacial deposition, or deposition from water. In detailed work these have been differentiated into a rather large number of soil series on the basis of the features of the soil profile, these being determined in large part by differences in drainage, relief, stages of profile development, and details of rock character. The soils are mainly immature in stage of profile development. They partake, in chemical composition, of the character of the rock, therefore, and since this is predominantly sandstone or shale, the differences among the several soils will be presumably small. The limited amount of chemical work done on these soils to date has been concerned mainly with maturely developed soils.

The imperfect development of the profile of the predominant soils of the region is due to their occurrence on slopes. Associated with these are a number of soils without normal profile development, owing mainly to the influence of high ground water during the period of soil development.

One of the important groups of mature normally developed soils of this region has been given independent status as the Wooster series.

The chemical and mechanical composition of a sample of the silt loam from Wooster, Ohio, are shown in Table 57.

TABLE 57.—*Composition of Wooster silt loam, Wooster, Wayne County, Ohio* [1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28510	A_1	0–2	[a]71.66	0.83	3.05	6.62	0.17	0.89	0.38	1.59	0.50	0.27	0.11	13.98	100.05	0.487	------
			[b]83.30	.96	3.55	7.70	.19	1.03	.44	1.85	.58	.31	.13	------	100.04	------	------
28511	A_2	2–18	[a]80.27	.95	3.74	8.63	.06	.36	.45	1.91	.67	.18	.12	3.00	100.34	.053	------
			[b]82.74	.98	3.85	8.89	.06	.37	.46	1.97	.69	.19	.12	------	100.32	------	------
28512	B_1	18–30	[a]76.10	.98	5.52	10.12	.04	.32	.75	1.92	.71	.22	.11	3.36	100.15	.045	------
			[b]78.75	1.01	5.71	10.47	.04	.33	.78	1.99	.74	.23	.11	------	100.16	------	------
28513	B_2	30–36	[a]75.47	.85	6.14	10.31	.09	.34	.83	2.15	.95	.21	.13	3.08	100.55	.036	------
			[b]77.85	.88	6.33	10.63	.10	.35	.86	2.22	.98	.22	.13	------	100.55	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28510	A_1	0–2	1.2	3.1	1.0	3.7	11.8	62.2	17.0	100.0
28511	A_2	2–18	1.1	2.4	1.0	3.2	22.7	51.3	18.3	100.0
28512	B_1	18–30	.9	2.6	1.5	6.4	26.8	42.1	19.8	100.1
28513	B_2	30–36	1.0	3.6	1.4	7.0	30.0	35.8	21.1	99.9

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Oct. 13, 1920.
[3] Analyzed by A. A. White.

The parent glacial drift was not reached in sampling. The percentage of clay increases progressively downward. The A_1 and A_2 horizons show clearly the influence of podzolization on the percentages of both iron oxide and alumina. The percentage of CaO in the thin A_1 horizon with its high ignition loss due to the presence of organic matter, is high. This is the usual relationship of calcium oxide percentages found in the Podzolic soils throughout the eastern part of the United States.

A few soils from the Pacific northwest, belonging it seems to the Gray-Brown Podzolic group, have been sampled and analyzed. They will be discussed in connection with the soils of the region as a whole.

RED AND YELLOW SOILS

The southeastern part of the United States is occupied by a group of soils covering about the same number of square miles as the Gray-Brown Podzolic soils. They are designated here as Red and Yellow soils. The color of the dominant mature soils

FIGURE 23.—Young growth of longleaf pine (*P. palustris*) on Norfolk fine sandy loam, Jackson County, Miss.

of the region is red or reddish, but yellowish soils cover large areas. These, however, seem to differ in color from the dominant soils because of local rather than regional conditions, so that the regional profile color is red. It is not yet known, however, whether the red color of the soil is permanent or merely an expression of relative youth or early maturity. Whatever may be the reason for the red color and whether permanent or temporary, the fact is that the most abundant maturely developed soils of the region at the present time are red or reddish. The red or reddish soils occupy regions where drainage is good and where the water table lies many feet below the surface. Yellow soils occur predominantly on smooth relief where ground water stands at a depth of a few feet, usually immediately below the solum, or has stood at that position until a very recent geological date. Yellow soils also occur locally in situations where the ground water lies far below the solum, but such soils are dominantly if not exclusively derived from sandy material, usually sands or loamy sands. The dominant Yellow soils throughout the region are sandy but not sands, and there are large areas of sandy materials which have developed into reddish and red soils. The grouping of the soils into Red and Yellow can not be done entirely on the basis of the texture of the parent material.

Although these soils are designated as red, or reddish, and although that color characterizes the greater part of the total thickness of the soil layer, in the fully or maturely developed soil the surface layer is invariably yellowish or grayish. Where the red color extends to the surface the soil is either immature or the light-colored surface horizon has been removed. This has taken place over large areas.

On the basis of existing knowledge, which is by no means complete and decisive, the boundary between the region occupied by the Red and Yellow soils and that occupied by the Gray-Brown Podzolic soils, extends from the mouth of Chesapeake Bay westward and southwestward through Virginia, across western North Carolina, gradually rising southward into the Blue Ridge in southern North Carolina, thence westward to the valley of east Tennessee, northward along the eastern side of the valley to the northern part of the State, westward and southward, as shown on the map, into east-central Texas, and southward to the Gulf. The region includes all or parts of the Southeastern States, Louisiana, southern Arkansas, and the eastern part of Texas.

This is a region in which the soils have developed under a cover partly of conifers and partly of deciduous trees, mainly oak. In the sandy part of the region, pine is dominant. In that part where the soil is derived from less sandy material, oak constitutes an important element in the forest vegetation, but pine is present. The rainfall is high, ranging from 30 to nearly 60 inches a year, and the average summer temperature ranges from about 75° F. in the eastern part of the region to 80° in the western part. The average winter temperature ranges from 40° around Chesapeake Bay to about 47° in eastern Texas.

These soils differ from those of the Gray-Brown Podzolic group not only in their dominant red or yellow color, but also in a lower percentage of alkalies and alkaline earths and of silicate silica, and in a higher percentage, where textures are comparable, of iron and alumina. They differ from them also in the more thorough eluviation of the profiles of Red and Yellow soils and a wider difference of textures between the A and B horizons. This is especially true of those soils derived from rocks containing a considerable quantity of sand, and such rocks are more abundant in the region of Red and Yellow soils than in that of Gray-Brown Podzolic soils. The more thorough leaching and eluviation of these soils expresses, in part, the results of a higher rainfall and in part the results of prevailingly higher temperatures. As the prevailing temperature is higher than in the Gray-Brown Podzolic region, the same amount of percolating water will be more effective in the decomposition of soil minerals and in the leaching of the constituents, especially of the bases and silica, than where the temperature is lower. The more extensive eluviation, and the much wider occurrence of soils derived from sandy material in the Southeastern States become readily explainable. The color is an expression of the relatively high temperatures and possibly of the effect of long summers, the latter parts of which are dry.

In general the region may be divided into two parts on the basis of the character of the parent material from which the soils are developing. One of these is a region of dominant sandy material, the other of heavier materials, although sandy materials are not entirely lacking. In geologic age the sandy material is young, the other old. The sandy material consists of unconsolidated sands and clays mainly of Tertiary age, constituting what is known as the coastal plain. The other differs widely in age but is predominantly Paleozoic and older. The older rocks range from crystalline gneisses and schists to limestones, shales, and sandstones. The regions with old rocks are known as the piedmont plateau and the Appalachian regions. The distribution of the different kinds of rocks is shown on the map (pl. 4); that of the group as a whole on Plate 2, and that of each of the soil series of the region on the sheets of the soil map of the United States, Plate 5, sections 7, 8, 9, and 10.

THE YELLOW SOILS

The Yellow soils are mainly members of the Norfolk and closely related series. They constitute the moderately well-drained soils in the coastal plain. They are designated on the soil map as Norfolk because the soils of that series are dominant and the most nearly normal soils within the region. The Norfolk soils occupy a broad belt in the coastal plain extending from the mouth of Chesapeake Bay southward and westward into Texas, although they are not dominant west of Georgia. They are the dominant soils through the Carolinas, extending into Georgia. Southward in Georgia and westward from that State, they become gradually less and less extensive. (Fig. 23.)

The normal profile of the sandy loam, the dominant type, is characterized by a thin layer of pine needles with some leaf mold from deciduous trees, underlain by about 3 inches of sand stained dark with organic matter. The grains of sand are usually gray. The third layer, constituting horizon A_2, consists of pale-yellowish sand or loamy sand extending to a depth ranging from a foot to several feet, depending partly on the texture of the parent material, partly, it seems, on the strength of the eluviating forces, and partly on the relief. These two layers constitute the A horizon. They are structureless, not even showing the lamination which is so widespread in the A horizon of the Gray-Brown Podzolic soils. The A horizon is underlain by yellow or faintly reddish yellow friable sandy clay, the B horizon, which is usually entirely structureless and extends to a depth of somewhat more than 3 feet. The color is uniform and locally may have a reddish shade. This layer is underlain by mottled red, yellow, and gray sandy clay.

RELATION TO SASSAFRAS SOILS

The Norfolk soils are the dominant soils of the coastal plain south of Chesapeake Bay and correspond, therefore, to the Sassafras soils north of the bay. Although they lie in a more southern latitude and have developed under a higher temperature than the Sassafras soils and theoretically, therefore, should have a higher constituent of red in their color than the Sassafras, the relationship is exactly the opposite. The Sassafras soils are slightly reddish in the B horizon, the Norfolk soils are less red. The reason for this seems to lie entirely in the drainage conditions under which the two soils have developed. The Sassafras soils occupy rolling areas. The surface of these areas lies, in most places, below the level of the original upland, and is the product of erosion, mainly during the existing cycle of topographic development. The Sassafras soils, therefore, have good surface drainage because of their relief. They are underlain by material lighter in texture than the material of the B horizon and also lighter in texture than the material underlying the B horizon of the Norfolk soils. Both surface and subsoil drainage of the Sassafras soils are good.

The Norfolk soils, on the other hand, lie on very smooth areas. They are underlain by material heavier than that underlying the solum of the Sassafras soils. Since the Norfolk soils lie on smooth or flat areas and presumably on the original upland surface not yet completely invaded by the developing streams of the existing drainage cycle, it is apparent that ground water lay at the surface only a relatively short time ago. On account of the invasion of the region by the present cycle of erosion, ground water has been reduced to a level ranging from 3 to 5 feet beneath the surface, and since that reduction took place, normal soil development has been in progress. To what extent the lack of dehydration is responsible for the yellow color in the Norfolk soils, and its presence in the Red soils of the region is responsible for their red color, can not yet be determined. The percentage of iron oxide in the colloid of the B horizon of the Norfolk soils in North Carolina is about 13.[14] That in the same horizon of Cecil sandy loam, a Red soil, is about 18.[15] The color of the colloid from the Norfolk soils is yellow, no change in color having taken place by removal of the sand from the material responsible for the color. The difference in the percentage of iron oxide in the colloid of the two soils does not seem to be sufficient to cause the difference in color. Since it is well known that the red color of iron oxide increases as the amount of combined water decreases and since it is also well known

[14] See Table 58.
[15] See Table 107.

that powdered hematite, which contains practically no combined water, is red, whereas that of limonite is yellow, it is apparent that the red color may, in this case, be due to a lower percentage of hydrated iron oxide in the Red soils rather than to a high total percentage of iron oxide.

An examination of the soil map (pl. 5, secs. 8, 9, and 10) shows that the Norfolk soils occupy the central part of the coastal-plain belt. The western part of the belt in the Carolinas and in part of Georgia is occupied by sand, and the eastern part along the coast and extending inland for a few miles is occupied by other soils, dominantly members of the Coxville series. The central belt of the coastal plain, occupied mainly by Norfolk sandy loams, is the best drained part, except that part where the parent material consists of sand. That of the sandy loam consists of sand and clay. This part of the coastal plain lies higher and presumably has been above sea level longer than the low-lying part in which the Coxville soils are dominant. It is therefore more thoroughly dissected, but the stage of topographic development is only in its early youth. Although areas in which the water table lies at the surface are small, areas in which the surface still lies practically at the original constructional level are large, and it is on these areas that the Norfolk soils have developed. They have developed, however, because the dissection has been sufficiently thorough to reduce the level of ground water to a depth ranging from 3 to 5 feet below the surface, leaving a layer free from ground water, thick enough for the development of an A and B horizon.

RELATION OF NORFOLK TO PORTSMOUTH-DUNBAR GROUP

In the low-lying part of the coastal plain, the Coxville belt, Norfolk soils are present, but they have a characteristic distribution. They are confined almost exclusively, in the Carolinas where the typical Norfolk soils occur, to belts along the valley borders. The large streams flowing across the coastal plain from the piedmont region, as well as the larger streams originating in the coastal plain have cut

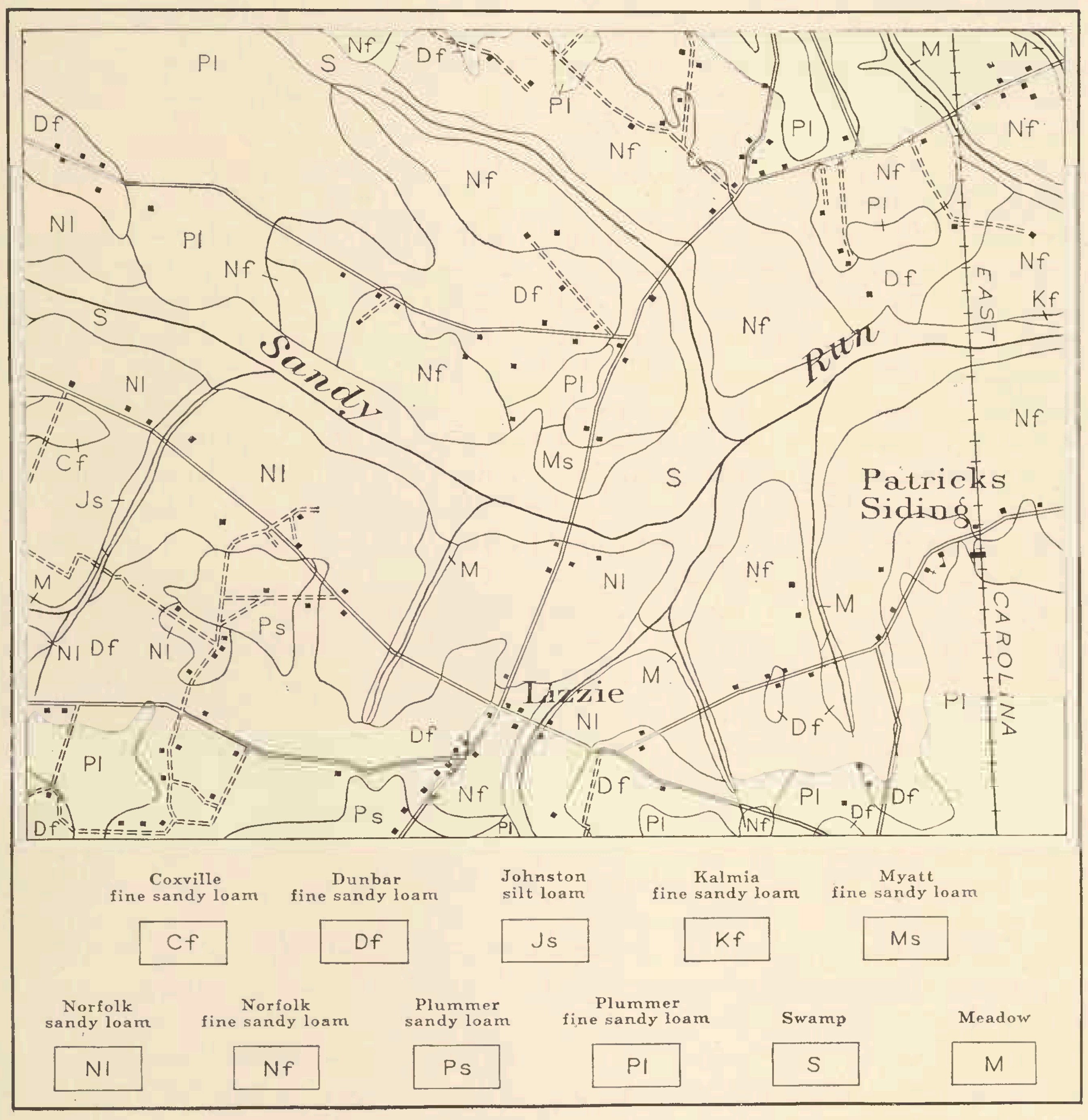


FIGURE 24.—Section of soil map of Greene County, N. C., illustrating the proximity of the Norfolk soils to the stream valleys, with Dunbar, Coxville, and Plummer soils on the broad, flat, poorly drained interstream areas.

shallow valleys across this lower belt. These valleys range in depth to about 50 feet. By means of tributary rivulets, which have worked their way backward from the main valleys, a belt lying along the sides of the latter has been dissected sufficiently to reduce the ground water level far enough below the surface for the development of a normal solum. This relationship is not so well shown on the large map as on the detailed maps. The small map (fig. 24) shows this relationship. In this belt of good drainage, Norfolk soils have developed. Immediately along the river bluffs in many places, reddish soils have developed, but the belt of these soils is very narrow, whereas immediately back of them is a belt of Norfolk soils which extends inland as far as drainage has reduced the level of ground water low enough for a normal or approximately normal solum to have developed.

Inland from these streams and occupying the still undissected surface of this low belt of the coastal plain the soils are poorly drained because the ground water level lies at the surface or only a short distance below it. It is evident that in the centers of these interstream areas the level of ground water will be highest and it will decrease gradually toward the streams. The center of the areas where the ground water still lies at the surface is occupied by dark-colored soils or by organic accumulations. The former are members of the Portsmouth series occurring in similar situations not only in the Norfolk region but in the Sassafras region as well. Since they consist of poorly drained soils, not yet having begun normal development, it has not been considered necessary to separate those in the region of Gray-Brown Podzolic soils from those in the Red and Yellow soils region.

Between the dark-colored soils in the centers of the undrained areas and the Norfolk soils in the valley-border belts are belts in which the water table lies slightly below the surface but still too high for the development of a normal soil profile. It is not high enough to prevent decay of organic matter and the soils are not dark in color. They are poorly drained from a very few inches below the surface downward, this being shown by their uneven color which is mottled red, gray, or brown. These are soils shown on the soil map (pl. 5, secs. 8 and 9) as members of the Coxville series. In detailed mapping a series intermediate between the Norfolk and Coxville soils, in which normal development has extended to a depth of somewhat more than a foot, is differentiated. A well-defined A horizon has been developed and an imperfect thin B horizon. In detailed mapping such soils are differentiated as members of the Dunbar series and correspond to the Keyport soils in the Sassafras belt of the Gray-Brown Podzolic region.

THE SAND-HILL NORFOLK

Along the inner border of the coastal plain is a belt of sand. This is shown merely as Sand on the soil map, but in detailed mapping it is mapped as Norfolk sand. The color profile is very similar to the Norfolk profile so far as the solum is concerned. The C horizon, or the material beneath the solum, is different from the corresponding horizon in the normal Norfolk. The surface layer, beneath a very thin cover of partly decomposed pine needles and oak leaves, is gray sand with a slight staining of organic matter at the top. This is underlain by pale-yellow sand ranging up to a foot or two in thickness and this, in turn by yellow sand. The yellow color is somewhat paler than that in the B horizon of the Norfolk sandy loam, and the texture is no heavier than sand. However, there is enough fine material in this layer, the B horizon, to give it a slightly loamy feel. The C horizon is mottled also, but the mottling seems to be different from that under the sandy loams. It consists of bright red, gray, and yellow spots. The distribution of the several colors is highly significant. The gray and yellow spots and streaks are confined to cracks and root channels or other openings, such as insect borings. It is evident from their location that the gray or yellow spots and streaks are due to the removal of iron oxide, and the red-colored spots, between cracks and other openings, are present where the iron has become thoroughly oxidized because of good drainage and where it has not been removed through leaching. It is noted that leaching has here extended well below the B horizon giving this sandy Norfolk soil a profile in which the C horizon is different from that of the normal sandy loam.

THE TIFTON SOILS

A large area of Tifton soils lies in the southern part of Georgia, mainly on the watersheds between the streams flowing eastward into the Atlantic and those flowing southward or slightly southwestward into the Gulf. These soils have been differentiated, in detailed mapping, from the Norfolk because of the occurrence in the soil profile of a large amount of clay ironstone fragments, weathered roundish, having the appearance of ironstone concretions. (Fig. 25.) It is apparent that they are not concretions in most cases but are fragments, imperfectly rounded through weathering, of ironstone plates. These developed in the upper part of the C horizon and, as the original level of the country was slowly reduced by sheet erosion, the soil profile developed downward at about the same rate as the surface level was lowered by erosion. The horizons of the solum have invaded the level at which the ironstone plates developed. After this has taken place the plates and their fragments constitute part of the A and B horizons. In becoming incorporated in these horizons they are broken into fragments and weather into roundish bodies.

FIGURE 25.—Profile of Tifton sandy loam, Tift County, Ga.

The Tifton soils occur on smooth uplands in situations where the erosion of the existing cycle of topographic development has not been active but where it has been sufficient to produce a gently undulating surface lying slightly below the original upland level. They do not lie, therefore, in situations exactly comparable to those of the Norfolk soils, since the latter lie on surfaces that have not yet been reduced below the original constructional surface level.

In profile characteristics, such as color, texture, and structure as well as in the relative thicknesses of the A and B horizons, these soils are very similar to the Norfolk soils. The A horizon of the Tifton soils is a little stronger in color than the A of the Norfolk, presumably because of the presence of more or less powdered material from the ironstone fragments, and the B horizon is faintly brownish with a very slight suggestion of reddish color. It has also a faint yellowish-green shade, whereas the Norfolk B horizon is purer yellow. The C horizon of the Tifton soils is much like that of the Norfolk soils, but in the Norfolk soils the spots where the iron oxide has accumulated are not yet indurated, whereas in such spots in the Tifton soils they have been indurated. This is interpreted as an indication of the better drainage that has very recently been developed in the Tifton soils due to the lowering of the ground water level by erosion. It is apparent that the color of the B horizon of the Tifton soils is partly due also to the fine material resulting from the disintegration of the ironstone fragments. These being mainly limonitic, the color is necessarily yellowish.

Associated with the Tifton soils in south-central Georgia, considerable areas have been mapped as Norfolk soils. (Fig. 26.) These lie on rolling relief and at lower levels, measured in relation to the level of the original constructional surface, than the Norfolk soils in the Carolinas. They lie in situations where the original surface has been eroded sufficiently to have reduced its level somewhat, and the

Norfolk soils have developed from material exposed by this erosion and therefore on material exposed by the erosion of the existing cycle. These soils have developed, therefore, from recently exposed material and are in a sense younger than are the Norfolk soils of the Carolinas. The C horizon also is not water-logged to the extent that is true of the C horizon of the true Norfolk soil of the Carolinas.[16]

LEON AND NORFOLK SANDS OF FLORIDA

The lower part of the coastal plain, which extends from Chesapeake Bay southward along the coast, expands in southeastern Georgia to a width of nearly 100 miles. The soils in this area, as shown on the soil map, consist mainly of members of the Leon series and organic soils, such as muck and peat. Small areas of sand occur here and there within this area, also smaller areas of Portsmouth soils, together with soils of a few other series, such as Plummer. Like the Coxville soils in a similar belt in the Carolinas, these soils are all poorly drained.

The Leon soils have a characteristic profile, however, consisting of a moderately dark-colored surface horizon extending to a depth of 3 or 4 inches and underlain by white sand which, in turn, is underlain at a depth of about a foot by an indurated dark-brown or coffee-brown horizon consisting of sand cemented mainly with organic matter containing very little iron oxide. In many places, the cementing material is organic matter entirely. This layer, in turn, is underlain by gray or white sand. This profile, in its general morphologic features, is essentially identical with the Podzol profile where developed in sand. The Leon soils, however, have developed under the influence of high ground water, the surface of which stands, during a large part of the year, a short distance below the surface. The layer of accumulated organic matter seems to mark this level. These soils lie in practically flat areas. They cover large areas in Florida along both the east and west coasts, extending almost to the extreme southern end of the peninsula, and they extend northward along the lower part of the coastal plain to North Carolina. The Lakewood soils in New Jersey have a somewhat similar profile, but they are true Podzols, having developed on rolling sand areas where ground water lies several feet beneath the surface.

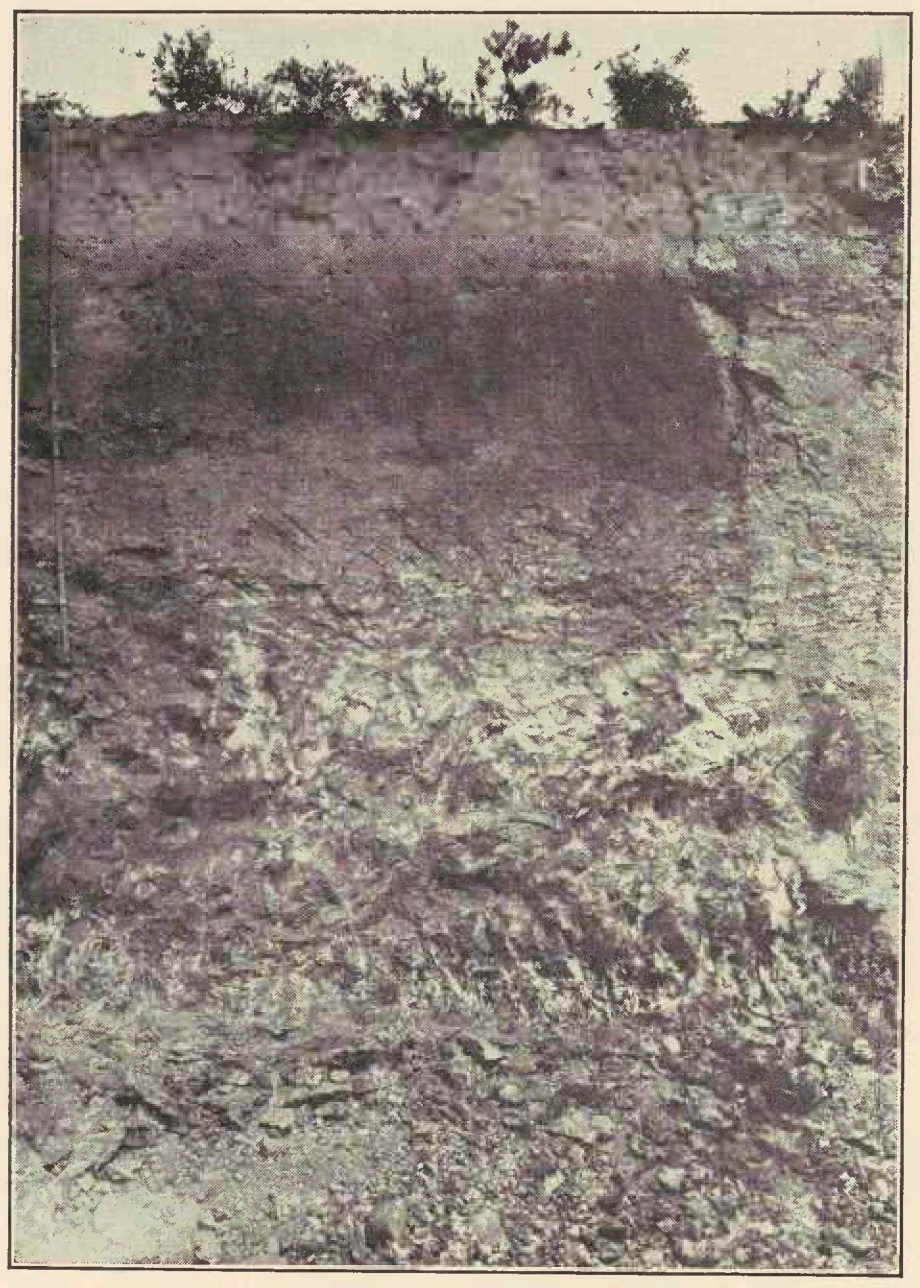


FIGURE 26.—Profile of Norfolk fine sandy loam, Wayne County, Ga.

On the soil map the central part of the Florida peninsula is mapped as Sand. In detailed mapping this sand is mapped as Norfolk sand or Norfolk fine sand, just as the sand-hill region of the Carolinas is mapped. In a large part of this central Florida belt, which consists of a low ridge, the Sand is underlain at a depth ranging from 10 to 20 feet by impure limestones, the sands seemingly having accumulated through the decomposition of these limestones and the removal from the decomposed product of the material finer than sand. The sands, therefore, seem to be residual. The soil profile is essentially like the profile of the sand-hill Norfolk region in the Carolinas to a depth of 6 or 8 feet, but below that it consists mainly of grayish sand rather than the mottled red, gray, and yellow sand beneath the solum of the sand-hill soils.[17] There seems to be also more clay in the deep C horizon of the sand hills than in this sandy belt of central Florida. In both regions the sandy soils are covered by scrub oak, together with some longleaf pine. Small areas of soils heavier than sand occur in this ridge belt of Florida, being shown on the map as Fellowship soils.

Flanking the main sand ridge in Florida, especially on the west, are areas of Sand differentiated partly because they are underlain, in places at least, by marls. Some of these sand areas also occur along the east coast, occupying an almost continuous belt from Jupiter Inlet northward to Jacksonville. This belt includes some areas of heavier highly calcareous soils which are used for the production of truck crops. In the extreme southern part of the peninsula is an area mapped as Rockdale soils which consist of a very thin layer of reddish soil overlying limestone rock. This is flanked on the west by a large area mapped as Parkwood soils consisting of highly calcareous clay or marl with a thin soil cover. In addition to these soils there are large areas of organic soils consisting of peat and muck scattered well over the State, mainly in the Leon area but occurring also in the sand belt. The largest area consists of the region known as the Everglades in the southern part of the State.

RED SOILS OF THE COASTAL PLAIN

The sand belt of the sand hills of the Carolinas extends into Georgia, but the belt in the latter State is much narrower than in the Carolinas. It continues across Georgia in a practically continuous belt and extends well into Alabama lying, as in the Carolinas, along the inner coastal-plain boundary. The map shows a broad belt of Orangeburg soils immediately south of this sandy belt in Georgia. It begins near the east side of the State and extends southwestward across the State parallel to the inner boundary of the coastal plain nearly to the western boundary where it turns southward as a continuous belt almost to the southern boundary. South of this, it occurs in smaller areas in southern Georgia and northern Florida. These are Red soils, either red from the surface downward or red in the B horizon only. They are mainly sandy loams but include some clay loams, those that are red or reddish from the surface downward consisting mainly of the heavy-textured types. The A horizon is essentially identical in color, texture, and structure, as well as in chemical composition, with the Norfolk soils. The B horizon, however, is bright-red sandy clay, very friable but practically structureless as in the Norfolk soils. In lack of structure, as well as in friability, these soils are identical with the Norfolk soils but differ greatly from the latter in color. Those soils which are red from the surface downward, being predominantly heavy in texture, are well differentiated in the normal A and B horizons. There is, therefore, usually a reddish A horizon and a deeper red B horizon. The reddish color in both soils extends down to a considerable depth, in some places more than 10 feet.

The Orangeburg soils have developed from impure limestones, and it is apparent that their red color is due mainly to this. In the southern part of the United States, as well as in the Mediterranean region of southern Europe, limestone materials, especially where the limestones do not contain a high percentage of clay, but may contain a considerable percentage of sand, develop into red or reddish soils. It is apparent that the red color will develop more fully in a far southern latitude from a limestone containing a higher percentage of clay than farther northward.

This belt of Orangeburg soils constitutes that part of the coastal plain of Georgia which was cultivated before the Civil War. The soils are somewhat more productive than the Norfolk or Tifton soils. They were covered by a mixed forest of oak and pine. The relief is either rolling, and therefore somewhat stronger than the relief on which the Tifton soils lie, or is gently rolling to undulating, having been made so through the attainment of base-level conditions in the region by the existing cycle of erosion.

Orangeburg soils continue westward into Alabama and occur in small areas in Mississippi. In southeastern Alabama, it is apparent that much of the soil shown on the map as Orangeburg is true Orangeburg, having been developed from limestone material, but in Mississippi, except in the central-eastern and northeastern parts, most of the soils shown on detailed maps as Orangeburg, are not true Orangeburg, but are merely sandy soils derived from sandy clays, usually underlain by sand, of the same character as the material from which the other associated sandy soils have developed[17a]. Associated with the Orangeburg soils in southern Alabama are large areas of Norfolk, with considerable areas of Ruston and Susquehanna, and small areas of Tifton soils.

The Ruston soils are reddish Norfolk soils. By this is meant that they have developed from unconsolidated sand and clay material identical in character with that from which the Norfolk soils have developed, but have developed in areas where the relief is stronger because of more thorough dissection by the existing cycle of erosion, where the ground water level stands well below the surface, where the drainage for a long time has been good, and where oxidation has been sufficient to give to these soils a reddish color in the B horizon. The A horizon, however, is essentially identical in character with the A horizon of the Norfolk soils. These soils are eluviated essentially the same as the Norfolk soils, the A horizon consisting mainly of pale-yellow sand or loamy sand, with the usual dark-colored surface layer of the virgin soil. The B horizon consists of reddish-brown sandy clay and the C horizon of sand and clay material, usually reddish yellow but without the mottling characteristic of the corresponding horizon of the Norfolk soils. Ironstone plates like those underlying the Tifton soils are not universally present, such mottling as is present in the C horizon of the Ruston soils being due apparently to incomplete oxidation rather than to the presence of ground water. The Ruston soils, therefore, must be considered more nearly the true normal soils of the region in which they occur than either the Tifton or Norfolk soils. In stage of development they belong with the Orangeburg soils, both having reached their normal stage of profile development. The Orangeburg soils have developed from limestone materials, the Ruston soils from sand and clay.

The Ruston soils occur in the southwestern part of Alabama, the area consisting of an extension eastward of a large area of these soils in southern Mississippi. Another belt of Ruston soils occurs along the coastal-plain border in northern Alabama. These soils have developed on strongly rolling and hilly relief from relatively coarse, in many places gravelly, coastal-plain material, and correspond to a greater or less extent to the sand-hill Norfolk soils of the Carolinas and Georgia. This belt may be considered as an extension of the sand-hill belt. The soil material, however, either contains a higher percentage of clay than that in the sand-hill belt or eluviation has not extended to so great extent as to produce such a thick layer of sand as seems to have been developed in the sand-hill belt.

HOUSTON, OKTIBBEHA, AND SUSQUEHANNA SOILS

Between the northern Ruston belt and the southern belt of Orangeburg, Norfolk, Tifton, and Ruston soils in Alabama lies a broad belt which may be designated as the clay belt. It is also a belt of low relief, compared with that of the Ruston belt to the north or of the Orangeburg-Norfolk belt to the south. It is a lowland belt for the same reason that the Orangeburg belt in western Georgia is a lowland belt, having been reduced to a lowland of smooth relief during the progress of the existing topographic cycle. It is underlain by a series of clays and marls, the latter often designated as rotten limestone. The marls consist of very fine grained limy clays containing 25 per cent or more of calcium carbonate. The clay beds associated with the marl contain, usually, more or less calcium carbonate but always less than that in the marl.

The soils of the marl beds are shown on the map as members of the Houston series. The characteristic Houston soils are black, with a profile imperfectly developed in all respects except color. The color profile, however, is not the normal profile of the region. It is, so to speak, a temporary profile having been controlled in its development by the very strong influence of the high percentage of calcium carbonate in the marly parent material. Because of the high percentage of calcium carbonate in this material and its disintegration to clay before the leaching out of the excessive calcium carbonate, these soils have not been good forest soils. The natural vegetation on this part of the clay belt, therefore, was grass or grass with scattered trees. The grass accumulated considerable organic matter and because of the high content of calcium carbonate and the heavy texture of the soil material, from which the calcium was removed very slowly, the organic colloids were fixed, through saturation by the calcium, and

[16] It may be stated here that in the future these soils, because of the different histories through which they have passed, may be differentiated from the Norfolk of the Carolinas. It may also be found that they have characteristics differing from the true Norfolk soils, in accordance with their different history of development.

[17] Reference is made here to the yellow, gray, and red sand lying beneath the solum in the sand hills and not to the mottled sandy clay underlying the sands at considerable depth.

[17a] Since these paragraphs were written the soils with an Orangeburg solum have been separated into two series—the Orangeburg soils developed from sand materials and the Magnolia soils developed from impure limestones.

were not removed from the soil by solution. The resulting accumulation of organic matter up to a relatively high percentage gave the soil its dark color. The surface layer is underlain by the unmodified marl or the marl that is slightly decomposed and more or less leached.

In Alabama, however, the Houston soils are rarely black. This is a result of the activity of soil erosion which removes the soil almost as rapidly as it develops from decomposition of the marl. In small areas only has the soil remained undisturbed long enough to accumulate sufficient organic matter to give it a dark color. In large areas the soil consists essentially of the unweathered marl. In detailed mapping such soils are mapped either as members of the Sumter series or as Houston

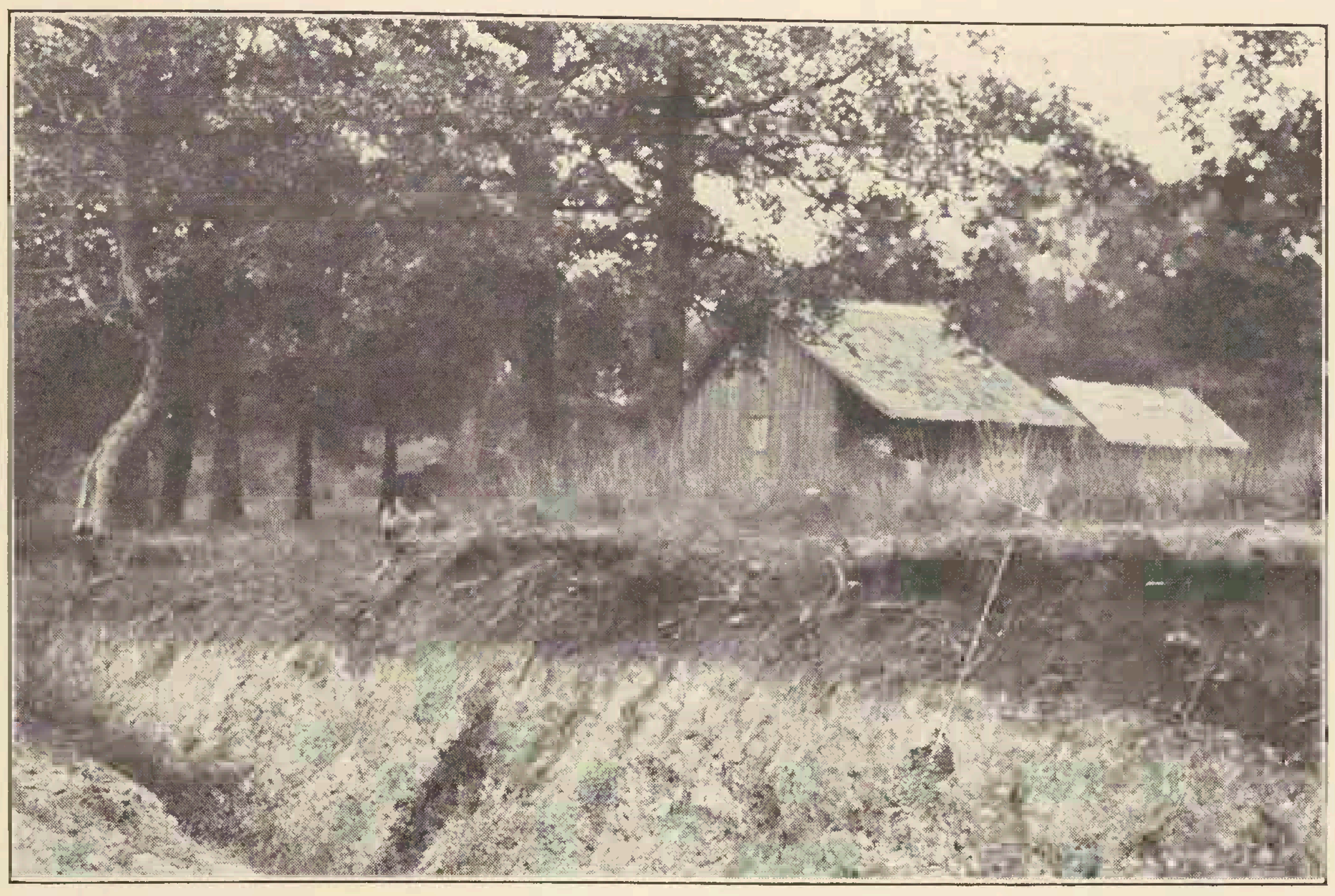


FIGURE 27.—Degraded Rendzina. Red soil (Oktibbeha clay), overlying calcareous marl, near Union Springs, Bullock County, Ala.

clay, and the soil that has reached a more advanced stage of development and is black, is mapped as Houston black clay. Houston black clay occurs in Mississippi along the extension of the Alabama belt into northeastern Mississippi.

The soils developed from the clays underlying the clay belt have attained a more normal stage of development than those developed from the marl. These are differentiated on the map into two soil series, the Oktibbeha and the Susquehanna. These soils lie mainly south of the Houston belt. The Oktibbeha soils seem to have developed from somewhat calcareous clays, whereas the Susquehanna soils have developed from clays very slightly calcareous or noncalcaeous. In both cases these soils are heavy in texture. In the Oktibbeha soils the profile is rather well developed (fig. 27), consisting of a light-colored silty A horizon and a red or reddish heavy crumbly clay B horizon. The clay of the B horizon breaks into angular fragments very similar in character to the fragments into which the B horizon of the dominant Gray-Brown Podzolic soils break. The Oktibbeha soils may be considered the normally developed soils from this heavy material. The carbonates contained in the parent materials, where such were present, have been leached entirely from the solum and from a thin layer beneath the solum constituting the upper part of the C horizon.

FIGURE 28.—Profile of Susquehanna sandy loam, Prince Georges County, Md., showing very slight development of a B horizon.

The Susquehanna soils occupy large areas in Alabama, Mississippi, Louisiana, and Texas. They have been mapped in the coastal plain as far north as Maryland (fig. 28), but true Susquehanna soils, similar to those in Alabama and Mississippi do not occur in Maryland. In Texas the Susquehanna profile is somewhat different (figs. 29, 30, and 31), as will be shown later, from that in Alabama and Mississippi. In the latter States it has, where the soil has developed from clay material, a very thin A horizon usually yellowish in color with the usual thin layer of dark-colored material at the surface. In some places the A horizon is no thicker than the dark-colored layer. It is underlain by the parent rock clays or somewhat sandy clays, essentially unweathered. There may be, in places, a thin layer of weathered clay immediately under the A horizon simulating, to that extent, a B horizon, especially if the parent material contains some sand or fine sand, but in the Susquehanna clay derived from clays containing practically no sand no B horizon is present. The C horizon consists of the plastic, tough, structureless, and unweathered parent-rock or heavy sandy clays, mottled red, yellow, and gray. The Susquehanna clay shown on the map throughout Mississippi and Alabama is essentially of this character. It will be noted, however, that the Susquehanna soils on the soil map (pl. 5, secs. 6, 7, 8, 10, and 11) are differentiated into the heavy or clay soil and the sandy soil. The sandy soil, occurring mainly in Louisiana and Texas, has a somewhat better developed profile than the clay. This is especially the case with regard to the A horizon which is normally developed and essentially identical with the A horizon of the Norfolk, Tifton, and Orangeburg soils. Beneath the A horizon, however, no B horizon has

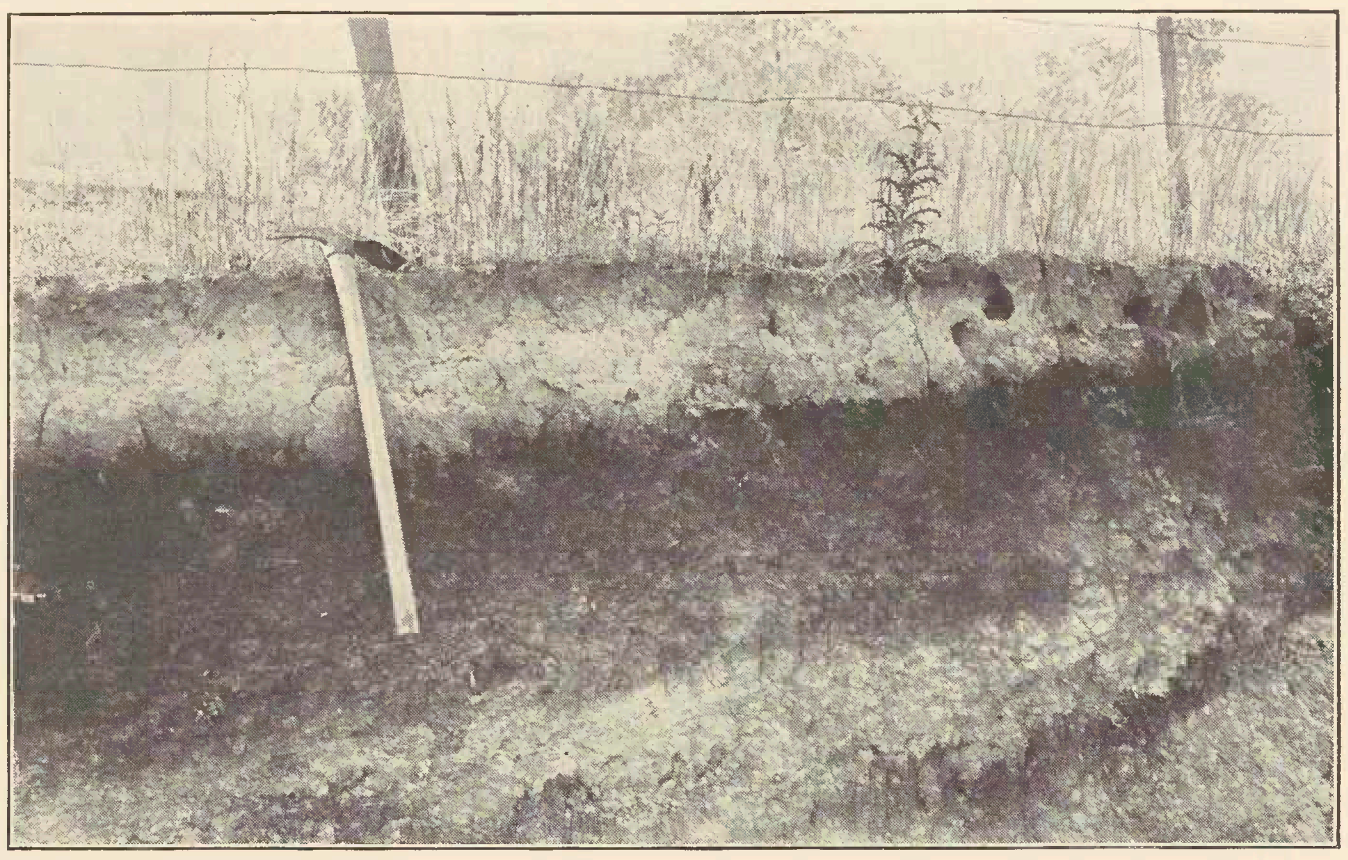


FIGURE 29.—Profile of Susquehanna sandy loam, Milam County, Tex.

developed in Alabama and Mississippi, the A horizon being immediately underlain by the parent material, essentially identical in its characteristics with the parent material of the clay, except that it contains a somewhat higher percentage of sand. In Louisiana and Texas a thin B horizon has developed.

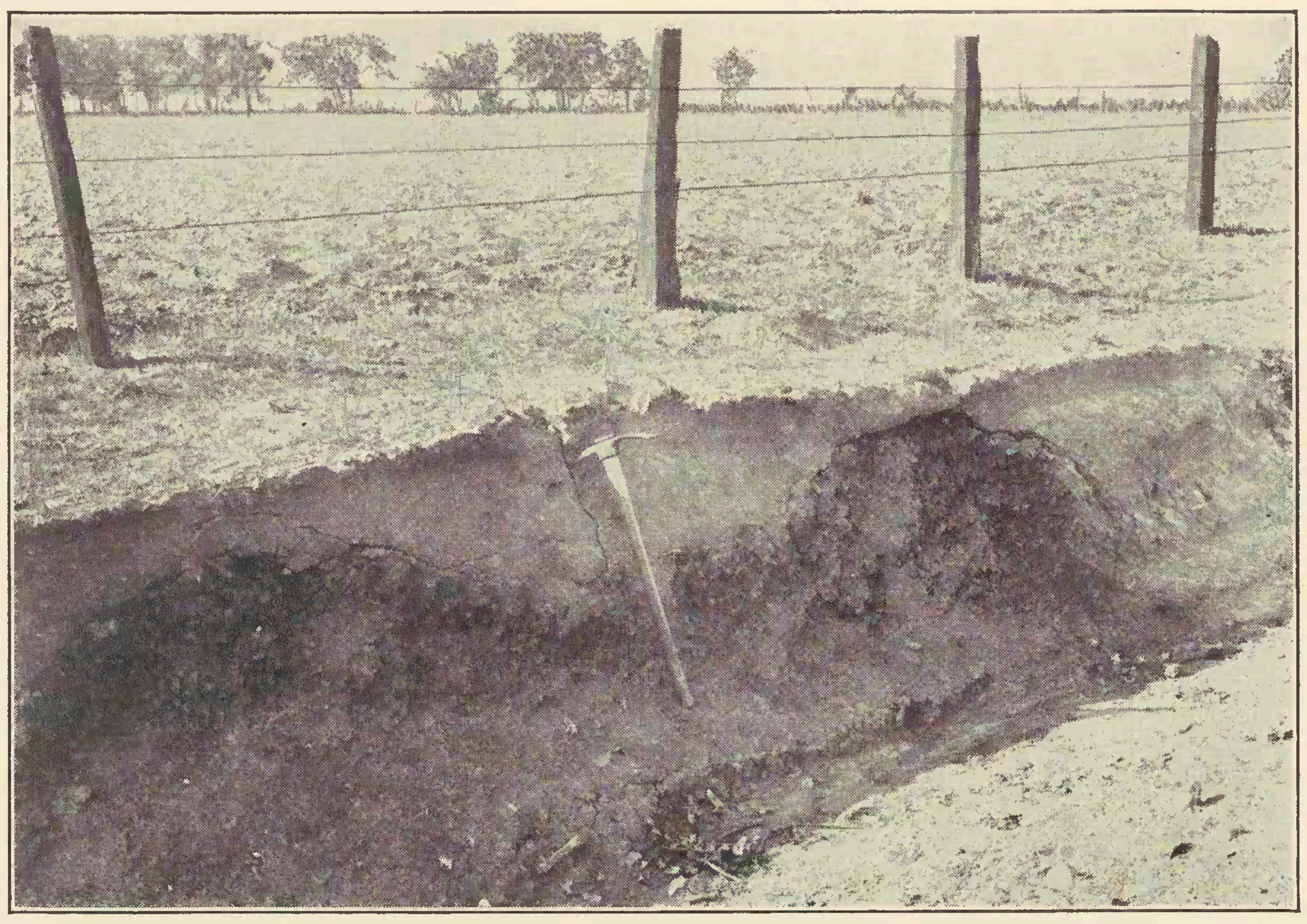


FIGURE 30.—Profile of Susquehanna sandy loam, Milam County, Tex., showing sandy A horizon, heavy clay B horizon, and undulating line of demarcation between A and B horizons.

RUSTON, CADDO, AND CROWLEY SOILS WEST OF THE MISSISSIPPI

The typical Ruston region is southeastern Mississippi just as the typical Norfolk region is the central belt of the coastal plain in the Carolinas. Small areas of Orangeburg and Susquehanna soils occur associated with the Ruston in this part of Mississippi. Along the coast in the southeastern part of the State is a belt of soils shown

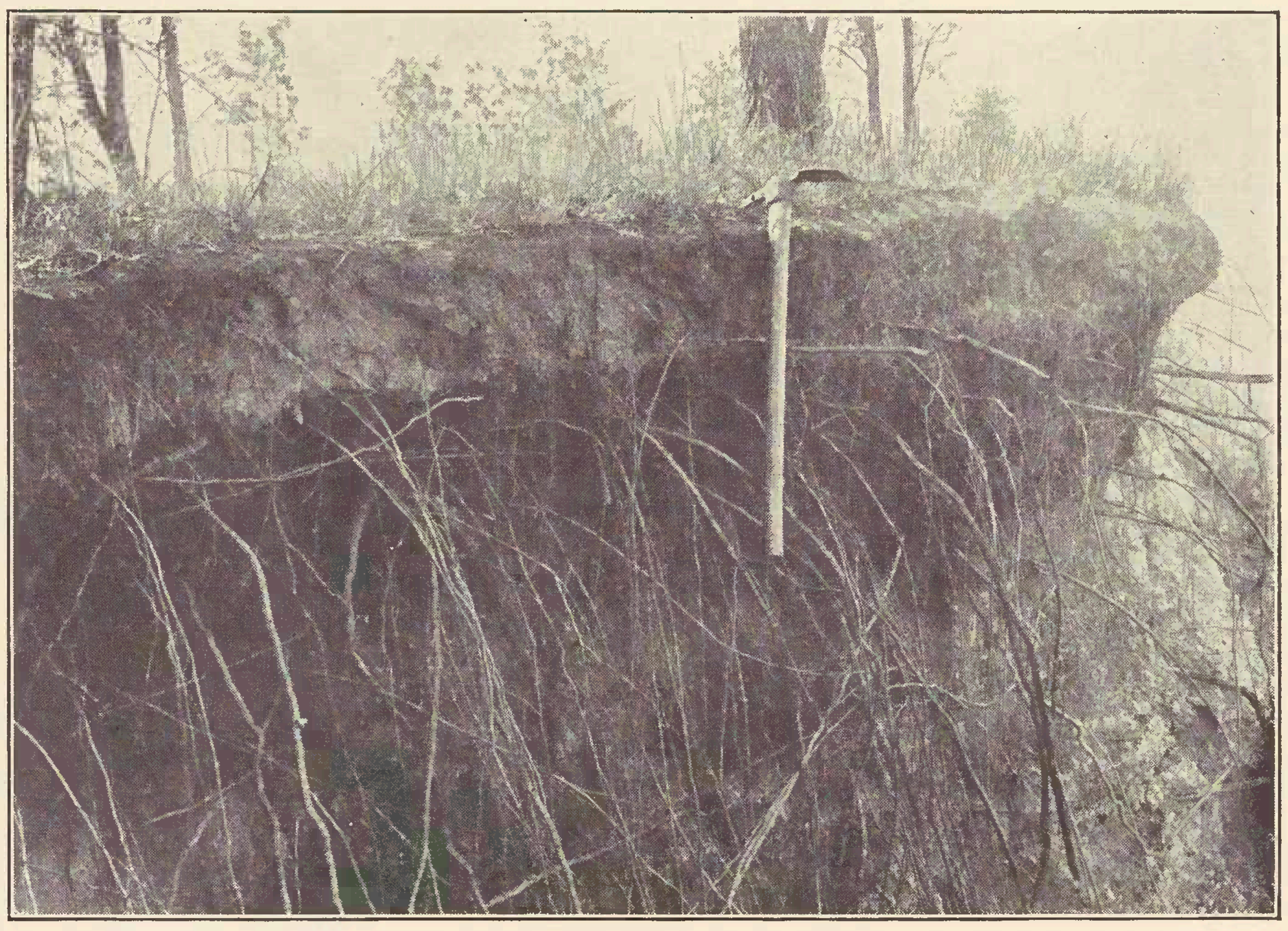


FIGURE 31.—Profile of Susquehanna fine sandy loam, Milam County, Tex., showing penetration of tree roots.

on the map as members of the Norfolk series. These lie along the coast in situations where drainage development has lowered the level of ground water to a depth of 3 or 4 feet from the surface. This has taken place recently, and a profile similar to that of the true Norfolk has developed from the sandy material. Small areas mapped Caddo occur in a few places in southern Mississippi. These soils have a

profile, or an A and B horizon, very similar to that of the Norfolk. The lower part of the B horizon, however, contains spots of gray and brown, changing downward to a slightly indurated horizon similar to that underlying the B horizon of the Leonardtown soils in the coastal plain of Maryland. These soils were developed under imperfect drainage and may be considered as Norfolk soils with an indurated upper C or lower B horizon.

West of the areas of Caddo soils and northwest of Lake Ponchartrain is a belt mapped as Crowley soils. These also are soils without normally developed profiles, in which the A horizon is somewhat like the A horizon of the Norfolk soils but less sandy. It is usually silty in texture and yellowish rather than gray like the Norfolk, the gray color in the latter being caused partly by the light color of quartz sand.

The A horizon in the Crowley soils is underlain by a heavy plastic tough clay, very hard when dry, which breaks into angular, sometimes cubical, blocks ranging up to an inch in diameter, these breaking further into very small angular particles. The outsides of many of these particles are reddish but may be brown or dark brown. No analyses have been made of these soils to determine whether the brown color is due to organic matter or to iron oxide. The same soils occur in rather large areas west of the Mississippi River in eastern Arkansas, and in small areas in southern Texas. When wet the heavy clay layer swells and becomes essentially impervious to moisture. Because of this characteristic these soils have been used extensively for the production of rice, the heavy clay layer preventing the loss through percolation of the water with which the crop is flooded. The heavy layer is underlain by mottled clay, usually rather heavy, and this in turn by sandy material. Eastern Arkansas may be considered as the typical area in which the Crowley soils occur. The belt as shown on the map includes other soils which are differentiated in detailed mapping, but because of their similarity they are included with the Crowley soils on the soil map in this Atlas.

MEMPHIS AND GRENADA SOILS

Memphis and Grenada soils extend along the Mississippi River bluffs and eastward over the uplands of Mississippi (fig. 32), Tennessee, and Kentucky in a belt more than 50 miles wide extending from the mouth of the Ohio River to the lowlands along the Gulf. These soils have developed from silty material identified by geologists as loess. The loess layer is thick along the river bluffs and thins eastward. Along the river bluffs the relief is hilly, having been produced by complete dissection by small streams and ravines working backward from the Mississippi flood plain, whereas eastward the dissection is less complete, especially in Mississippi. In western Tennessee and Kentucky, however, dissection is more thorough, but even in these States the eastern part of the belt is not so thoroughly dissected as is a narrow belt along the bluffs.

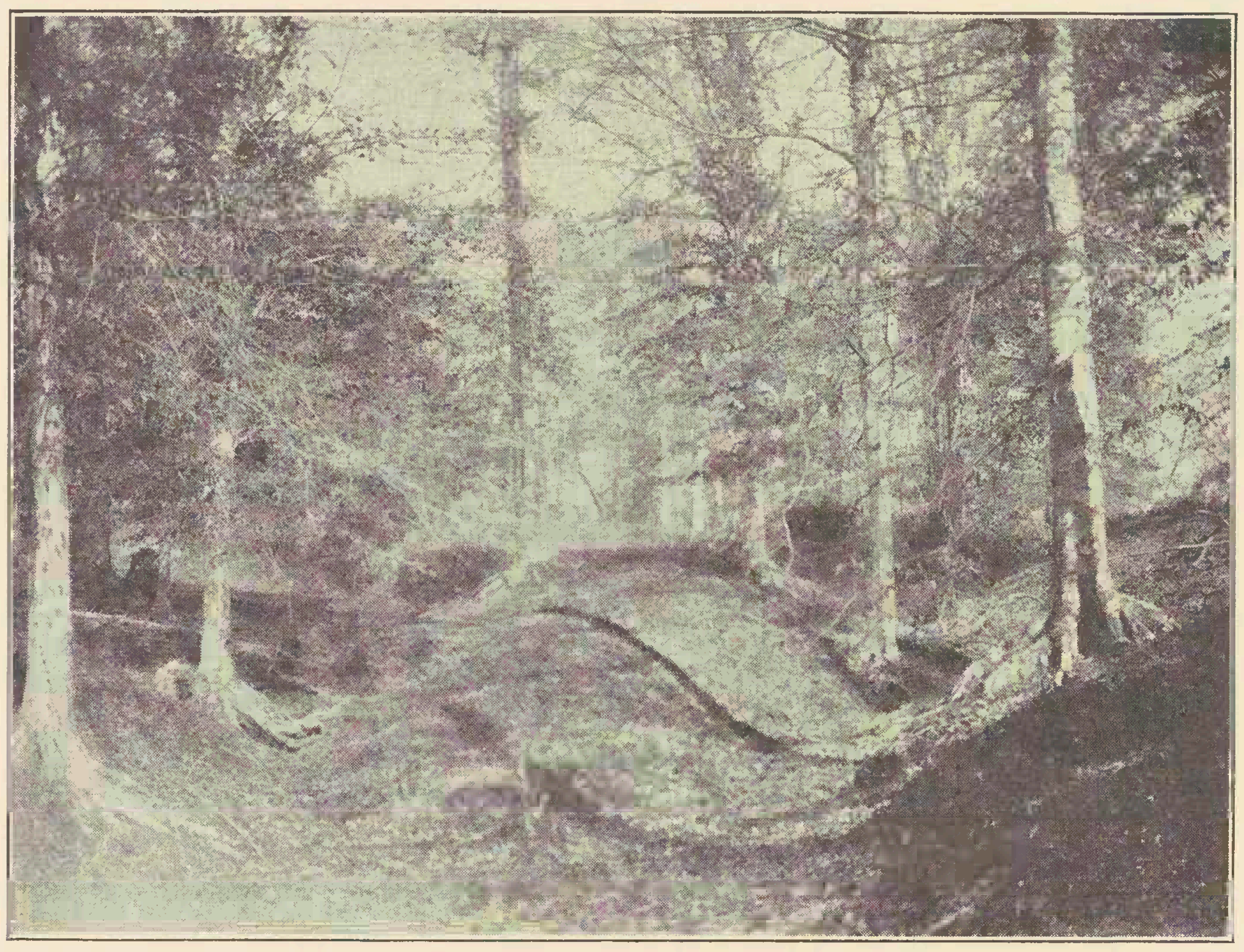


Figure 32.—Beech forest on Memphis silt loam, Yazoo County, Miss.

The loess is calcareous. In the very hilly valley bluff belt erosion keeps the surface down almost to the unleached material. This very young soil as well as the associated normally developed soil are shown on the map as Memphis. Where the normal profile has attained a moderately well developed state it has a yellowish A horizon with a 3-inch layer of dark-colored silty material at the top. The A horizon is underlain by a heavier reddish-yellow B horizon in which the material breaks into angular particles very similar to that in the B horizon of the Miami soils. The surfaces of the particles in the B horizon have a stronger color than the interiors, the latter being more yellow, while the former are slightly reddish.

The B horizon in its normal development is similar to the B horizon of the Cincinnati and Clinton soils of the Gray-Brown Podzolic region, but it is somewhat reddish. It is underlain by a C horizon from which the calcium carbonate has been removed by leaching to a depth of 10 feet or more, and this, in turn, is underlain by the unleached loess. Because the relief of the whole belt in western Kentucky and Tennessee is rolling, somewhat like the bluff belt in Mississippi, the belt consists entirely of Memphis soils in these States, though in detailed mapping other soils are identified.

Eastward from the belt of Memphis silt loam the loess belt becomes smooth. Because of the slow erosion in this belt, the soil material lies in place without disturbance longer than in the Memphis belt. Ground water for a considerable part of the year is rather high also. This belt is occupied by Grenada soils. (Fig. 33.) The Grenada silt loam has a profile almost identical in character, so far as consistence is concerned, with that of the Leonardtown silt loam. It consists of a normal A horizon, a normal B horizon, both similar to corresponding horizons of the Memphis, where the latter have developed, but the lower part of the B horizon becomes mottled with gray spots which at slightly greater depth grade into an indurated horizon similar to that of the Leonardtown soils in Maryland and of the Caddo in Mississippi. It is not indurated to so great an extent as is the corresponding horizon in the Leonardtown soils.

The Memphis and Grenada soils are not sandy, and to that extent are not true members of the coastal-plain soils. They differ also from the latter in being derived from calcareous material, this presumably being calcareous because of having its source in Mississippi River alluvium which has been derived, to a very great extent, from northern and western soils. The western soils on the Great Plains contain soil carbonate and in most cases the parent rock also is calcareous. In the northern soils the parent materials, though not the soils, are generally calcareous.

Memphis silt loam, where the profile has developed at all, and Grenada silt loam have assumed, however, in the characteristics of their profiles, the characteristics of the southern soils rather than the northern. The corresponding northern soils derived from what seems to have been identical material, occurring along the Missouri River in Nebraska and adjoining States, are entirely different and have been given independent status as members of the Knox and Marshall series.

SOILS OF THE EAST-TEXAS PINE BELT

The typical east-Texas country, with dominant Susquehanna soils, lies north of the belt of coastal prairies. The dominant Susquehanna soils are associated, however, with a considerable number of other soils, some of which have been differentiated on the map as Norfolk, some as Ruston, and a number are differentiated as other series in detailed mapping. These may be studied in the reports of the few detailed surveys which have been completed in east Texas. One of the important groups of soils associated with the Susquehanna consists of members of the Bowie series. They have developed from material similar to that underlying the Susquehanna but somewhat more sandy. The A and B horizons are similar to those of the Norfolk soils, but the parent material is heavier and the B horizon is heavier and somewhat tougher than the Norfolk B. On the soil map in this Atlas they have been included with the Susquehanna soils. They occur mainly in the northeastern part of the State.

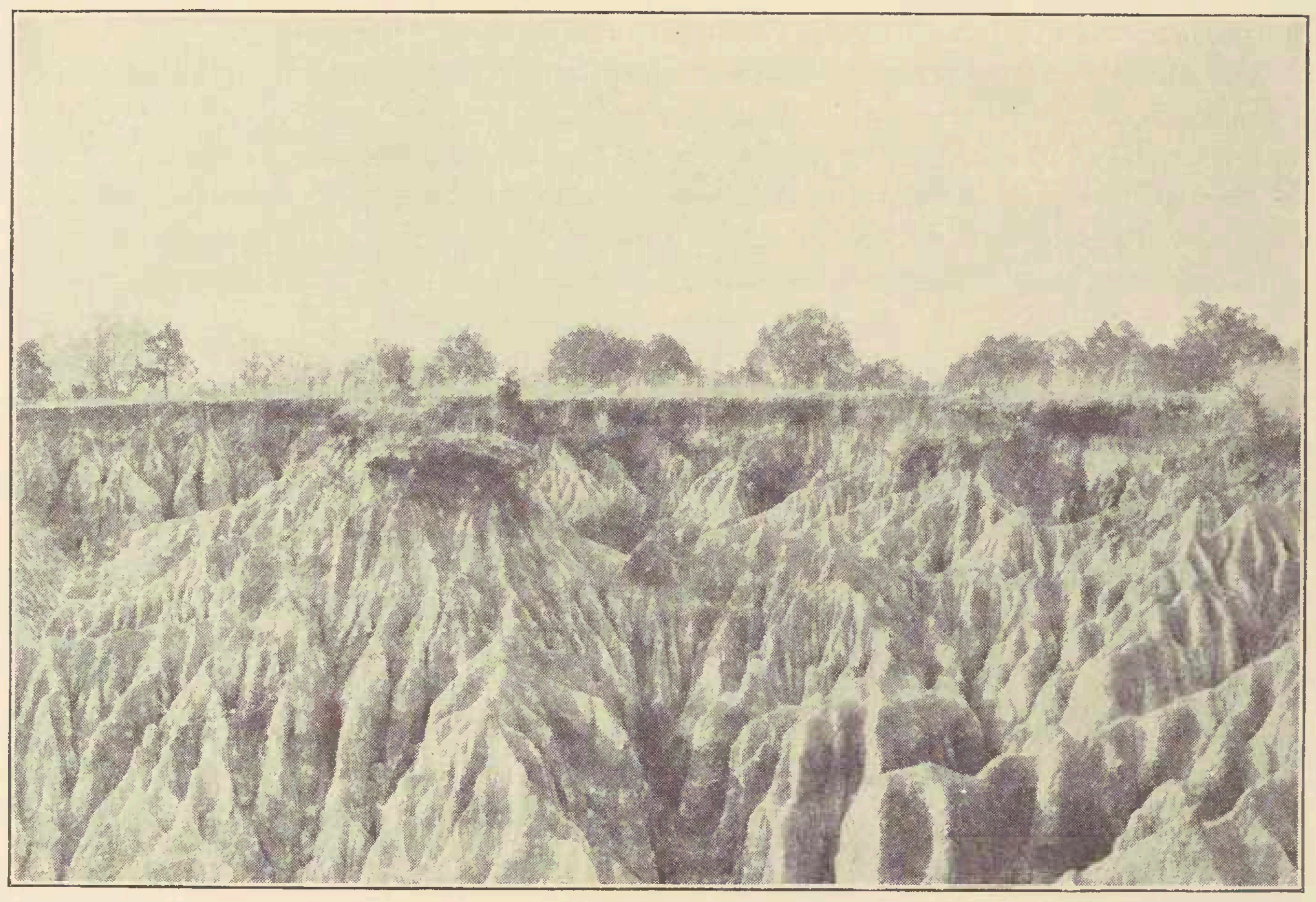


Figure 33.—Typical erosion occurring in Grenada silt loam, Madison County, Miss.

In the western part of the Susquehanna area in east Texas, the Lufkin soils become rather important. These are related to the Susquehanna but differ sufficiently to warrant differentiation on a generalized map. They differ also from soils that have been mapped as Lufkin in Alabama, Mississippi, and Louisiana (combined with the Susquehanna on the soil map, pl. 5, secs. 7 and 10) partly in the soil profile and partly in the color of the parent material. The latter, in the eastern States, is grayer and less well drained than in Texas. In Texas the Lufkin soils have also a profile characteristic of a well-advanced stage of development.

The A horizon is essentially identical in character with that of the Susquehanna soils of corresponding texture. Beneath the A horizon is a heavy, tough, plastic B horizon which breaks on exposure into angular, roughly cubical blocks ranging up to an inch in diameter and these in turn into smaller particles. The color of the outsides of the blocks is dark and of the insides is mottled. This is not the parent material occupying a comparable position under the Susquehanna soils, but is a developed horizon and is similar in its characteristics to the corresponding horizons of the Crowley soils in eastern Louisiana and Arkansas and the Katy soils of south Texas. It is underlain by material similar to the parent material of the Susquehanna soils.

The foregoing general description of the soils of the coastal plain, from Chesapeake Bay into east Texas, shows that wherever these soils have developed in a region of thorough dissection, where ground water level stands well below the surface and surface drainage is good and has been good for a long time, as shown by the stage of topographic cycle development, these soils have developed a reddish color wherever maturity of development has been attained. Where drainage is imperfect or has been imperfect until a recent geological date, these soils are yellowish, even though the ground water has lain several feet below the surface long enough for a normal or at least a subnormal solum to have developed. Soils of this character have been described as Norfolk and Tifton soils. Along with the reddish soils and these subnormal yellowish soils there are large areas of imperfectly developed soils which have been described as Coxville, Dunbar, Portsmouth, and under the names of a number of other well-known series.

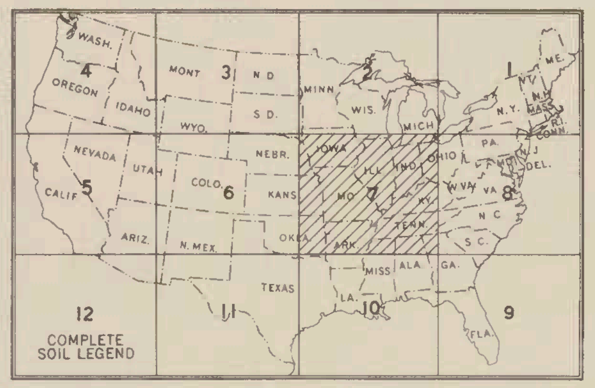
Another group of yellow soils in which the yellow color is not due to imperfect drainage, is that of very sandy soils such as the sand soils of the sand hills along the inner border of the coastal plain.

Lith. A. Hoen & Co., Inc.

LEGEND FOR THIS SECTION

Barnes	Durant	Lowell	Sierra
Bates	Durham	Marshall	Summit
Baxter	Eldorado	Memphis	Susquehanna
Caddo	Elk	Miami	Talladega
Carrington	Fairmount	Miller	Tilsit
Cecil	Fox	Moody	Clermont
Cherokee	Genesee	Muskingum	Vernon
Clarksville	Gibson	Ochlockonee	Volusia
Clinton	Grenada	Oktibbeha	Wabash
Clyde	Grundy	Olivier	Waverly
Conway	Hagerstown	Orangeburg	Waukesha
Cory	Hanceville	Parsons	Webster
Crawford	Hartsells	Plainfield	Wooster
Crete	Houston	Portland	Worth
Crosby	Huntington	Putnam	Marsh and Swamp
Crowley	Kirkland	Ruston	Peat and Muck
Davidson	Knox	Sarpy	Rough and Stony land
Decatur	Lindley	Sharkey	Sand, dark
Derby	Louisa	Shelby	Sand, light
Clarion	Lebanon	Cahaba	Norfolk

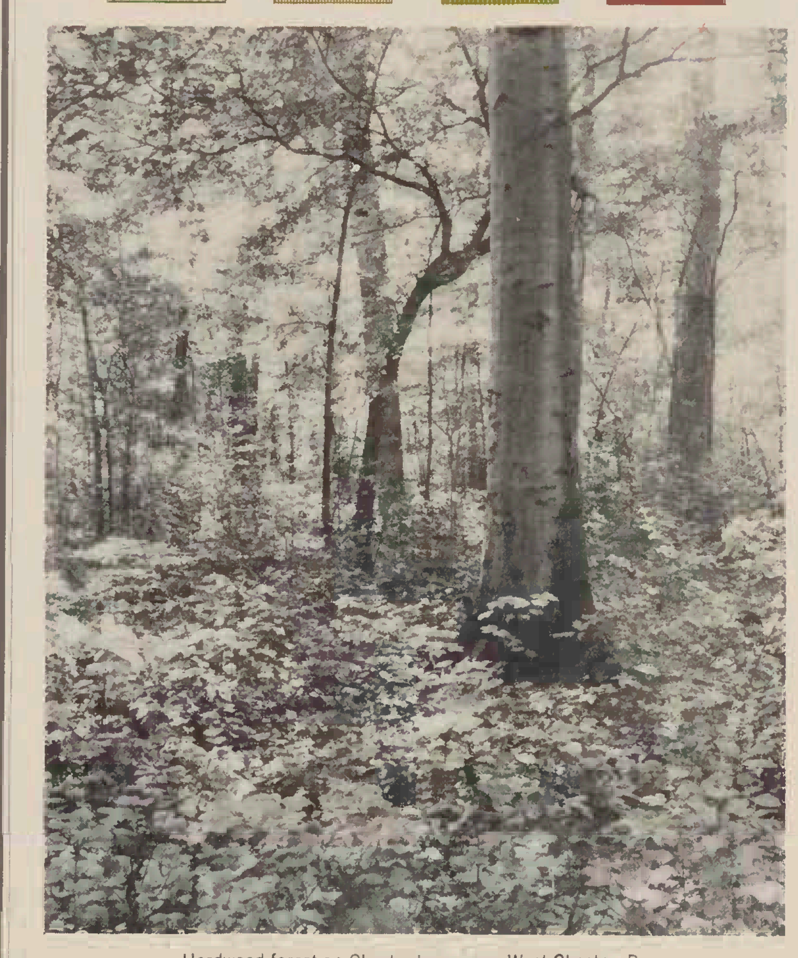
ARRANGEMENT OF SECTIONS



Lith. A. Hoen & Co., Inc.

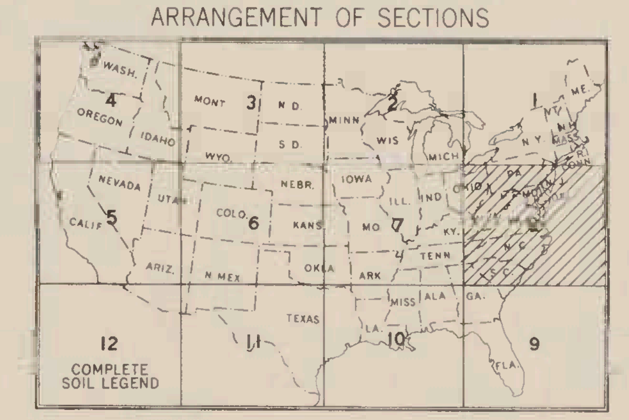
LEGEND FOR THIS SECTION

Alamance (Al)	Durham (Dur)	Meigs	Susquehanna
Bladen (B)	Dutchess (Dut)	Miami (Mia)	Talladega (Ta)
Cahaba (Ca)	Elk	Muskingum (MM)	Tifton
Cecil	Georgeville (Ge)	Myatt	Upshur
Chester (Chr)	Hagerstown	Nason	Volusia
Clarksville	Hartsells	Norfolk (N)	Westmoreland
Clyde	Huntington	Ochlockonee	Wethersfield
Collington	Iredell	Orangeburg	Wooster
Coxville	Lackawanna (Lac)	Penn	Marsh and Swamp
Davidson	Leonardtown	Plummer (Plu)	Peat and Muck
Decatur	Lordstown (Lor)	Portsmouth (Po)	Rough and Stony land
Dekalb	Louisa	Ruston (R)	Sand (S, Sd) light dark
Dunkirk (Dk)	Manor	Sassafras (Sp)	Waverly



Hardwood forest on Chester loam, near West Chester, Pa.

ARRANGEMENT OF SECTIONS



SOILS OF THE TERRACES AND ALLUVIAL PLAINS

Throughout the coastal-plain region south of Chesapeake Bay, relatively broad areas of terraces border the valleys of the large rivers. Some of these are well drained, some are imperfectly drained, but small areas only are poorly drained. The soils developed on these terraces are Red or Yellow soils, depending mainly on the perfection of drainage. The red and reddish soils have profiles essentially identical with those of the corresponding stages on the upland. The sandy materials develop profiles identical with those of the Ruston and Orangeburg, in localities where they are well drained. Where less well drained they develop into yellow soils like Norfolk. In detailed mapping these soils are broken up into a number of series, the yellow soils into the Kalmia, the poorly drained soils into the Myatt and Leaf, the well-developed soil with gray surface soil and red subsoil into Hannahatchie, or if the material be heavy and the soil red to the surface, into Amite, and the reddish soil with a Rustonlike profile into Cahaba. On the soil map these have been grouped into Myatt, Kalmia, and Cahaba, but they include areas covered by all the series mentioned and also a number of minor series differentiated in detailed mapping.

North of the mouth of Chesapeake Bay, in the region dominated by Sassafras soils, the soils on the terraces, where normally developed, are identified as Sassafras soils, there being no differentiation, in such cases, between the soils on the upland, if well developed, and those in equivalent stage of development on terraces.

The alluvial soils of the coastal plain in the Yellow soils region have been differentiated into a number of series. Over large areas, where they are low and subject to very frequent inundation, the soils are shown on the detailed soil maps, as well as on the map in this Atlas, as Swamp. If the material be brown or reddish brown, moderately well drained, made up mainly of material from the piedmont region, it is identified as Congaree. Congaree soils occur along the large streams in the Carolinas mainly but to less extent elsewhere. Along the lower parts of the large streams in the Carolinas and part of Georgia, where the alluvial soils under natural conditions are submerged during high tide, but by fresh water, the soils are mapped as Georgetown, mainly clay. Up to a few years ago these soils were protected by dikes and used for the production of rice.

In Alabama, the alluvium along the small coastal-plain streams is included in Swamp, along the large streams in the eastern part of the State as Congaree, and along the streams in the western part of the State and in Mississippi, where moderately well drained but subject to flooding, as Ochlockonee. The latter is the brownish alluvial deposit, mainly from upland coastal-plain material, corresponding to the Congaree.

SOILS OF THE MISSISSIPPI, ARKANSAS, AND RED RIVER FLOOD PLAINS

The dominant soils of the great Mississippi lowland have been shown on the map as members of the Sharkey and Sarpy series, mainly the former. In detailed mapping a number of series have been differentiated, including those mentioned, each of which is divided into a number of texture types.

The Sharkey soils are confined to the deposits containing a high percentage of clay. They occur mainly in the "back swamp" or that part of the flood plain lying far enough from the river banks not to be influenced by strong currents and the coarse deposits laid down in such places.

The Sarpy soils are mainly young natural levee soils, lying along the river banks and a short distance inland. They are predominantly relatively coarse in texture and are underlain at a depth of a few feet by still coarser material, usually sand. Yazoo soils are relatively old natural levee soils and have developed a soil profile. They lie on the natural levee in situations where they have not been disturbed recently.

The alluvial soils of the Mississippi flood plain are differentiated from those of the smaller streams of the region partly because of their prevailingly slightly darker color. This results from the derivation of the Mississippi River alluvium, to a considerable extent, from the prairies. These soils are less leached of bases than the alluvial soils of the coastal-plain or piedmont streams because the material has its source to a great extent in the soils of the Great Plains and prairies where the soils are rich in organic material and the bases.

A belt consisting mainly of Crowley and Waverly soils lies immediately west of the alluvial plain, mainly in Arkansas. Much of this belt lies west of Crowley Ridge in Arkansas in a broad valley formerly occupied by the Mississippi River and later abandoned. The Waverly soils are light colored, the surface horizon being almost white except a thin dark-colored layer at the surface. They have developed also under imperfect drainage on alluvial plains of small streams flowing mainly from the Ozark region in Arkansas. They occur also east of the Mississippi River, in Mississippi and other States. The profile is not yet developed. The Crowley soils have already been described on page 44.

The alluvial deposits of the Arkansas and Red Rivers contain a considerable amount of material from the red beds of western Kansas, Oklahoma, and northwest Texas. They are easily recognized by their red color and high percentage of calcium carbonate. The material which still retains its reddish color with slight leaching of the carbonates constitutes the soils of the Miller series. The older deposits, in which the color to a depth of more than a foot has given place to the normal soil color of the region, constitute the various members of the Portland series. These soils have a light-colored, pale-yellowish, or brownish-yellow A horizon and a much heavier dark-reddish B horizon which is underlain by pinkish or reddish clay. The clay material is highly calcareous, usually heavy in texture and, where the profile has not been developed far enough for the surface to have become leached, the soils are highly productive but rather difficult to cultivate and also, being alluvial soils, are subject to flooding. The Miller soils along both the Red and Arkansas Rivers consist of a belt of very fine sandy loam along the existing or recently abandoned channels, constituting a natural levee in which the profile is moderately developed although the carbonate has not been leached to a greater depth than about 2 feet. These soils are well drained. The rest of the alluvial plain consists of Miller clay which, because of its heavy texture and its subjection to frequent overflows, has not developed a profile.

THE RED SOILS

Under the discussion of the Yellow soils a number of red and reddish soils were included. The general heading Yellow soils referred more accurately to the soils of the coastal plain, including red, reddish, and yellow soils, than to yellow soils alone. The designation Yellow soils was justified because the dominant soils discussed under that head are yellow. In the same way the general heading Red soils will cover both red and yellow soils, but the dominant soils included under it are red or reddish.

The Red soils occupy considerable areas underlain by ancient rocks, both Archaean and Paleozoic. In the piedmont region and the Blue Ridge highlands, they are underlain by very old crystalline rocks and in the Appalachian and Ozark regions by rocks of Paleozoic age. In all cases the upland soils of the group have developed from material accumulated by the decay of underlying rocks consisting of crystalline schists and gneisses, limestones, sandstones, and shales. In general the area occupied by soils derived from these materials is well drained. Dissection is thorough, except locally, and is relatively deep. Although the rocks are relatively resistant to erosion, dissection has attained, as a whole, a more advanced stage of development than in large parts of the coastal plain.

While Yellow soils are not insignificant in their occurrence within the general region of Red soils, the areas occupied by them are not large. The relationships of the Red and Yellow soils within the region of Red soils, to the relief of the land on which they lie and have developed are identical with the relationships of the correspondingly colored soils to the relief on which they lie in the coastal plain. The Yellow soils occur predominantly on smooth or flat areas; the Red (and reddish) soils on rolling areas with good drainage produced by thorough dissection or by underlying gravels and sands. This is in general true, regardless of the character of the rock underlying the soil.

SOILS OF THE PIEDMONT REGION

The dominant soils in the piedmont region, extending from Virginia southward to Georgia and Alabama, including also part of the Blue Ridge plateau in North Carolina and Georgia, are members of the Cecil series. The two principal types, namely, Cecil clay loam and Cecil sandy loam, which in detailed mapping of the region are shown with a number of other types, have been combined under Cecil on the soil map of this Atlas. The Cecil clay loam is, from the point of view of area, much more important than the sandy loam.

While the true Cecil clay loam has developed from crystalline rocks containing a low percentage of quartz, the greater part of the soil mapped as clay loam is a soil derived from material containing quartz, in which the A horizon, originally sandy, has been removed by erosion, and the B horizon, containing a high percentage of clay, lies on the surface. Since in detailed mapping in the United States the final soil unit is differentiated on the basis of differences in texture of the surface layer, regardless of the relation of that material to the theoretical normal profile of the region, such a soil would be mapped as a clay loam. The sandy loam, on the other hand, has the normal profile of the region and is not one that has been mutilated to the extent of having suffered the removal of its A horizon. The normal profile of the region, that of the sandy loam, consists of the usual very thin layer of leaf mold at the surface, made up mainly of leaves from deciduous trees, but may contain, from place to place, different proportions of leaves from conifers. The leaf mold is underlain by a 2- or 3-inch layer of light-textured or very sandy material mixed with enough organic matter to give it a dark color and this, in turn, by pale-yellow or grayish-yellow structureless sand, loamy sand, or light sandy loam. These two layers constitute the A horizon, and both are usually structureless.

The B horizon is red clay containing some sand, the proportion of the latter differing greatly from place to place, depending on the percentage of quartz in the parent rock. The material breaks into angular particles similar to those in the B horizon of the Gray-Brown Podzolic soils in which the B horizon contains a rather high percentage of clay. In most places the color of the particles is redder on the outsides than on the insides. The thickness of the horizon differs somewhat with the locality, being less thick in the northern end of the piedmont region and thicker southward into Georgia where it extends to a depth ranging from 5 to 8 feet. It is underlain by reddish or yellowish loose material derived from disintegration of crystalline schists and gneisses not yet thoroughly decomposed. The unweathered gneisses and schists lie at depths differing greatly from place to place, attaining in places a depth of 100 feet or more. Rock decomposition has extended to great depths, but the solum is only slightly thicker than that in the region of the Gray-Brown Podzolic soils where the Chester soils are developed.

The profile just described is that of the sandy loam and is the typical mature and undisturbed profile not only in the piedmont region, but also, as has been seen, in that part of the coastal plain where the soils are red or reddish. Since the Yellow soils, as already explained, seem to be yellow because of local rather than regional conditions, the profile of Cecil sandy loam or that of Orangeburg or Ruston sandy loam must be considered the normal regional profile.

The important soils associated with the Cecil soils in the southern piedmont and Blue Ridge regions, most of which are shown on the map, are members of the Durham, Georgeville, Alamance, Davidson, Iredell, Louisa, and Talladega series. (Pl. 5, secs. 7, 8, 9, and 10.) They have been differentiated from the Cecil soils partly on the basis of profile characteristics and partly on the basis of the character of the parent material.

The Durham soils are yellow. Their profile in its fundamental physical features is identical with that of the Norfolk soils, it being apparent that both soils have developed under similar conditions. The Durham soils have developed, at least until a relatively recent geological date, under the influence of imperfect drainage. They lie on relatively small, flat, and as yet undissected, upland areas of the piedmont region. A similar soil, differentiated as the Appling on the detailed maps of this region, has been included with the Durham in this publication and on the soil map. (Pl. 5, secs. 7, 8, 9, and 10.) Both soils have developed from crystalline gneisses and granites.

The Alamance soils are similar to the Durham in color. They have developed from slates, however, and, as in most soils derived from such material, the whole layer of disintegrated material is thin, and in most cases no opportunity has yet been presented for the development of a normal soil profile even where other conditions have been favorable. The Alamance soils have a profile similar in some respects to that of the Durham but in large areas these soils are somewhat less strongly yellow than the Durham soils. Drainage is less perfect in part of the Alamance region than in the Durham.

The Georgeville soils are associated with the Alamance, but instead of lying on smooth or flat areas they lie on moderate slopes. The material has been accumulated from shales and slates, but the layer of accumulated material is thicker than on the

flat areas, has been well drained for a long time, and the soils have developed the normal profile of the region. The parent material, consisting of slates which contain a very low percentage of sand and a high percentage of silt and clay, has produced a silty A horizon and a rather heavy but very friable reddish clay B horizon. The A horizon is somewhat more reddish than the sandy A horizon of the Cecil sandy loam but is reddish yellow rather than red. The B horizon, however, is strongly red. Disintegrated or undisintegrated shale lies beneath the B horizon.

The Louisa soils occur in a number of localities but mainly in the western part of the southern piedmont and in the southern part of the Blue Ridge region. In essential characteristics they are Cecil soils derived from highly micaceous rocks. Because of the high percentage of mica and the slow rate at which this material decomposes, the profile has not yet become well developed. These soils are red, however, and are incipiently developed. Part of the lack of profile development is a result of the prevailingly rolling or hilly relief on which these soils occur. The Chandler soils are similar to the Louisa but are yellowish rather than reddish. As these soils have not been studied in detail, the reason for the yellowish color has not yet been determined. However there is some data available suggesting that the yellow color is due to imperfect drainage because of the slight depth to the dense schists.

In comparatively small areas throughout the piedmont belt, not only in the region of Red and Yellow soils but also in that of the Gray-Brown Podzolic soils, are occurrences of dark-colored igneous rocks, usually diabasic in character. Where freshly decomposed and where, partly because of slightly imperfect drainage and imperfect oxidation, no profile has yet developed, this rock has weathered to material consisting of extremely heavy plastic and tough clay. Soil profile development is very slight, the surface soil being very similar in color to the material beneath. Soils of this character are members of the Iredell series.

Where this material has become oxidized because of good drainage, the resulting soils constitute members of the Davidson series. They are red clay soils with slight profile development.

It will be noted that the Chester soils extend southward into the latitude of the Red and Yellow soils. They do not extend, however, into the Red and Yellow soils region but remain in the higher parts of the piedmont region in Virginia and North Carolina and in the Blue Ridge plateau of the latter State. The Chester soils in this region, however, have a relatively imperfectly developed profile because they lie on mountain slopes. The extent of their leaching and the general character of their profiles, where the development has taken place, are similar to the Chester soils in the northern piedmont plateau. They illustrate the vertical zonation of soils.

SOILS OF THE APPALACHIAN VALLEY AND RIDGES

The southern end of the Great Valley is much broader than that part lying in Pennsylvania, Maryland, and Virginia. It is underlain by cherty and chert-free limestones and by shales, some of which are calcareous. The dominant soils are members of the Clarksville series. They are developed from the highly cherty material from limestones. Because of the abundance of chert they have been well leached and have developed a profile with a gray or nearly white A horizon and a yellow B horizon, underlain by red clay with embedded chert.

The Clarksville soils, with their well-defined yellow color in both horizons of the solum, include on the soil map certain soils in Kentucky and central Tennessee where they are associated with Gray-Brown Podzo ic soils. They have been described, as far as knowledge of their characteristics allows, in connection with the Lowell and other Gray-Brown Podzolic soils. They could quite as well have been included in the Red and Yellow soils. They lie near the boundary between the two groups, this situation allying them, in some cases, with the Gray-Brown Podzolic soils, but their physical characteristics relating them to the Red and Yellow soils.

The same statement may be made regarding some of the soils shown on the map as Hagerstown, especially those in the southern part of Tennessee. These soils are red rather than yellow and are transitional soils belonging as nearly in the Red soils of the southeast as in the Gray-Brown Podzolic soils.

It will be noted that the southern boundary of the Gray-Brown Podzolic soils across Tennessee bends southward into the northwestern part of Alabama, along the Tennessee River, and then turns sharply northward along the Tennessee River to southern Illinois where it again turns westward. This part of the boundary is somewhat arbitrarily located, but, since the boundary between the Gray-Brown Podzolic soils and the Red and Yellow soils is not a line but a broad zone and since the heavier soils such as those developed from the limestone materials in the central parts of Tennessee and Kentucky have developed the characteristics of the Red and Yellow soils to less extent than those of light texture in the coastal plain of the Mississippi embayment, it has been considered permissible at least to include the soils developed from all of the relatively fine grained materials in the Gray-Brown Podzolic group rather than to put some in one group and some in another. The light-textured soils, however, those developing from sandy materials, have been more thoroughly leached than the heavier soils derived from limestone materials in the same latitude, so that within the coastal-plain region the Red and Yellow soils extend northward to the mouth of the Ohio River and also extend across the central part of the Ozark region, the boundary line across that region having been established somewhat arbitrarily on the boundary between those soils developed from limestones in Missouri and northern Arkansas and those derived from sandstones and shales in Arkansas.

The soils developed from chert-free limestones in the southern part of the Great Valley and in certain places in the central basin of Tennessee and the Ozark region, where the limestones are rich in carbonates, have red or reddish B horizons. They are identified as members of the Decatur series, the types consisting of the silt loam and clay loam. They occupy large areas in the Great Valley of eastern Tennessee, Alabama, and Georgia. These soils are relatively productive and occur on smooth relief, and the greater part of the land on which they occur is cultivated. Because of their rather heavy subsoil and the silty deflocculated condition of the surface soil, they have been severely eroded and a normal profile is of rare occurrence. Invariably, however, where a normal unmutilated profile is found, it consists of a relatively light colored A horizon and a stronger colored B horizon. The A horizon has the usual thin layer of leaf mold on the surface, a thin layer of dark-colored mineral soil immediately beneath it, and a thicker layer of pale-yellow or faintly reddish material underlying the latter. The B horizon is heavy but friable red clay, and it is underlain by disintegrated limestone material, often at considerable depths. Outcrops of limestone rock are numerous throughout the region.

These soils seem to have the same profile and, so far as is known, the same general chemical composition as the red loams overlying limestones in the more humid part of the Mediterranean region and Balkan peninsula. Although there has been considerable discussion as to whether the red loams contain an A horizon, the most recent work indicates that this horizon is present except where it has been removed by erosion. This is undoubtedly the case with the red limestone soils in the southeastern part of the United States, this relationship of red color to the A and B horizons being the same in the Decatur soils as in the Cecil soils. A yellow A horizon develops on the limestone soils just as well as on the Cecil, but it has been removed over large areas, not only where the soil has been cultivated, but also in virgin areas. The occurrence of the red color over large areas, not only in the region of dominant Cecil soils but also in the region of Decatur soils, means nothing more than that the A horizon has been removed by erosion. Since the material of the Decatur soils is relatively heavy, however, the A horizon is not so thick as the A horizon in the Cecil.

SOILS OF THE ALLEGHENY PLATEAU AND OZARK REGION

The Allegheny plateau in Tennessee and northern Alabama lies immediately west of the Great Valley without the intervening belt of Allegheny ridges, which is present in Pennsylvania and Virginia. In Tennessee and Alabama it consists of a series of long, relatively narrow, smooth-topped plateaus less thoroughly dissected than in Kentucky, West Virginia, and Pennsylvania. On these smooth uplands yellowish sandy soils have developed with profiles practically identical with the profiles of the Norfolk soils. They constitute members of the Hartsells series. Associated with them, usually in well-drained situations, are soils with red B horizons derived from sandstone and shale material, constituting members of the Hanceville series.

A large area of soils mapped as Hanceville lies in the southern or sandstone part of the Ozark region in Arkansas. This region is in part a plateau and in part a region of parallel alternating ridges and lowland belts caused by the erosion, through a series of erosion cycles, of folded interbedded resistant sandstones and nonresistant shales.

On all comparatively smooth areas consisting of remnants of the uneroded plateau and the well-drained parts of the lowland belts between the ridges the normal regional profile has developed, consisting of a light-colored sandy or silty A horizon and a reddish heavier B horizon. Small areas of Hartsells soils occur in the region on flat areas where ground water has stood at a depth of 3 or 4 feet and where indurated subsoils have not developed. In the lowland belts and smooth areas elsewhere the soils of the well-drained spots are members of the Hanceville series. On flat areas in the lowland belts the soils have developed indurated subsoils. They are members of the Conway series. Soils on steep slopes are members of the Muskingum series. Because of the small scale of the map, only Hanceville and small areas of Conway soils are shown.

It will be noted that the Muskingum soils have been extended from the typical region in which they occur in the northern Allegheny Plateau of eastern Ohio and western West Virginia southward into the region of Red and Yellow soils. They not only extend into the latitude of the Red and Yellow soils but also into the environment of these soils. In detailed mapping they are not extended so far southward, but on the soil map in this publication they are so shown because they are young soils and have not yet developed a profile. When they develop a profile in this southern region they will have the profile, not of the Gray-Brown Podzolic soils, but that of the Red and Yellow soils. In the localities where drainage is thorough they will develop a Hanceville profile and where it is still good, but less thorough, a Hartsells profile. At the present time these are neither Hartsells nor Hanceville soils but are very young soils without profile, derived from sandstone and shale material. Although in most cases such soils would be given an independent name because of the evident course which their development is taking and will take, yet because of the small scale of the map and of the large number of differentiations already on it, they have been identified, for the purpose of the soil map, as Muskingum soils despite their occurrence in the region of Red and Yellow soils.

A small aggregate area of Holston soils is mapped, as silty members of the Hartzells soils in small areas, in the southern part of the Great Valley. Other areas are mapped in southern Indiana and in other places in the Tennessee-Kentucky-Alabama region. They are normally developed Yellow soils, having developed on flat areas from water-laid noncalcareous materials, and they are essentially identical in general character with the Norfolk soils.

In rather large areas of eastern Oklahoma soils have been developed from sandstones and shales in a hilly region, smoother, however, than the Ozark region of Arkansas. Sandstones constitute an important part of the rock. The soils are sandy, have a reddish B horizon, and have been placed on the map in the Hanceville series. Soils developed from the same kind of material, somewhat finer in grain, along the western border of the Ozark region in Missouri have been identified in detailed work as members of the Bolivar series. They differ from the Hanceville soils in that the color of the B horizon is less red and the material is heavy, rather tough, and intractable clay. The profile is not normal, whereas that of the Hanceville soils is normal.

COMPOSITION OF THE RED AND YELLOW SOILS

COMPOSITION OF NORFOLK AND TIFTON SOILS

No attempt has yet been made to trace in detail the differences in chemical character found in the soils of the eastern part of the United States as one proceeds from north to south. Samples have been collected somewhat at random and a considerable number have been analyzed, but very little has yet been done except to determine, by fusion analysis, the total quantities of constituents present. No samples of virgin Yellow soils from the coastal plain in North Carolina have yet been analyzed. The composition of samples of material, seemingly representing moderately well the A and B horizons, but collected in a cultivated field at Scottsville, in eastern North Carolina, was published by Robinson and Holmes (*15*) in 1924. The results, including the composition of colloid extracted from both horizons, are shown in Table 58.

TABLE 58.—*Chemical composition of Norfolk fine sandy loam, Scottsville, N. C.*[1] [2]

Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	0- 8	[a]90.34	0.94	1.88	2.89	0.001	0.100	0.080	0.22	0.04	0.02	0.03	3.74	100.28	0.060	-----
		[b]93.90	.98	1.95	3.00	.001	.104	.083	.23	.04	.02	.03	------	100.33	------	-----
		[c]38.25	.79	11.25	31.21	.033	.540	.530	.26	.09	.23	.08	16.51	99.77	.220	-----
		[d]45.81	.95	13.47	37.38	.040	.640	.630	.31	.11	.28	.10	------	99.72	------	-----
B	12-36	[a]85.69	1.06	2.67	7.62	.005	.310	.070	.40	.21	.01	.06	3.08	101.18	.030	-----
		[b]88.41	1.09	2.76	7.86	.005	.320	.072	.41	.22	.01	.06	------	101.21	------	-----
		[c]41.60	.71	11.28	31.10	.005	.340	.490	.46	.22	.26	.05	13.81	100.32	.250	-----
		[d]48.27	.82	13.09	36.08	.005	.390	.570	.53	.26	.30	.05	------	100.36	------	-----

[1] Collected by B. B. Derrick. [2] Analyzed by W. O. Robinson and R. S. Holmes.

The samples were not collected by horizons, and none was collected from the C horizon. The data therefore do not make it possible to determine what differences exist between the parent material and the soil or whether sesquioxides have accumulated in B or have merely been removed from A. The composition of the "surface soil," which constitutes part of the A horizon, shows a low percentage of iron oxide and alumina, and that of the "subsoil," which includes a part of the B horizon but may also include part of A, shows higher percentages of alumina and iron oxide and lower percentages of silica than the layer above. The sa ratio in the colloid material of the surface soil calculated from the composition of the "loss-free" material is 2.08. That in the colloid from the subsoil is 2.24. That of the colloid from the B_1 horizon of the Chester loam in Arlington County, Va. (see p. 33), is 2.14.

The composition of samples of a profile of Norfolk sandy loam from Bennettsville, S. C., is shown in Table 59. Since the maximum depth of samples was 36 inches only, the parent material seems to have been merely touched, only part of the material from 27 to 36 inches being from the C horizon. The material from 8½ to 27 inches represents the upper part of the B horizon. The A and B horizons were carefully separated in sampling.

TABLE 59.—*Composition of Norfolk sandy loam, Bennettsville, S. C.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34736	A_1	0-2	[a]91.64	0.66	0.73	0.97	0.03	0.30	0.21	0.11	0.22	0.01	0.03	5.09	100.00	0.080	------
			[b]96.53	.70	.77	1.02	.03	.32	.22	.12	.23	.01	.03	------	99.98	------	------
34737	A_2	2-8½	[a]93.37	.66	1.13	1.57	(3)	.24	.18	.15	.24	.02	.02	2.42	100.00	.060	------
			[b]95.64	.68	1.16	1.61	(3)	.25	.18	.15	.25	.02	.02	------	99.98	------	------
34738	B	8½-27	[a]84.32	1.06	2.62	8.27	(3)	.17	.18	.16	.20	.02	.02	2.98	100.00	.040	------
			[b]86.88	1.09	2.70	8.52	(3)	.18	.19	.17	.21	.02	.02	------	99.97	------	------
34739	C	27-36	[a]85.94	1.06	2.16	7.64	(3)	.13	.16	.19	.26	.01	.03	2.42	100.00	.030	------
			[b]88.06	1.09	2.17	7.83	(3)	.13	.17	.20	.27	.01	.03	------	100.04	------	------

Sample No.	Horizon	Depth	Mechanical [4]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34736	A_1	0- 2	2.9	21.6	18.7	15.5	10.7	21.4	9.1	99.9
34737	A_2	2- 8½	2.1	18.2	18.4	16.4	11.9	21.4	11.4	99.8
34738	B	8½-27	1.9	17.3	15.8	14.0	9.7	19.3	22.0	100.0
34739	C	27-36	2.8	16.8	16.1	13.7	10.1	18.3	22.1	99.9

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Dec. 8, 1917.
[3] Trace.
[4] Analyzed by L. T. Alexander.

The several ratios and the molecular equivalent composition are shown in Table 60.

TABLE 60.—*Norfolk sandy loam, Bennettsville, S. C.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
34736	A_1	0- 2	160.90	332.21	1.07	------	------	------	------
34737	A_2	2- 8½	100.90	218.50	.64	1.59	0.007	0.016	0.010
34738	B	8½-27	17.33	85.27	.10	1.44	.017	.083	.008
34739	C	27-36	19.12	107.58	.11	1.46	.013	.076	.008

The sa ratios and molecular equivalent composition show that the gain of alumina in the B horizon over that in C is small but that the loss from A_2 has been great. Since the horizon designated here as C is partly lower B and partly upper C, this small difference is to be expected. It is evident that the gain in B is not sufficient to cover all the loss suffered by A, even if no diminution of volume has taken place in A and much less so if diminution has taken place. There must have been considerable loss of alumina from the profile. In the case of iron oxide the gain in B can not be accounted for by the loss from A, providing again no change in volume of A has taken place. In a soil with so high a percentage of silica, in which also about 85 per cent or more of it is quartz, any change in volume brought about by the shifting of colloidal material, consisting in this case of very finely divided iron oxide and aluminum silicate, is not great or rapid. It is apparent that the iron oxide has been saved and that most of the alumina has been lost. This difference in relative persistence of iron oxide and alumina is also well brought out, especially for the A horizon, by the iron-oxide alumina ratios which are 461, 202, and 177, respectively, for the A_2, B, and C horizons. The A horizon ratio shows that the iron oxide has been retained to a very much greater extent than the alumina. The B horizon shows similar results but to a much smaller degree.

The difference between the sa ratio in C and that in B must in this case be accounted for practically entirely by accumulation of alumina in B. Since the material consists of sedimentary sands and clays, the amount of undecomposed mineral in it other than quartz is very small. The actual accumulation has, however, been small, amounting to about 10 per cent of that in C. The accumulation of iron oxide has been greater, amounting to about 20 per cent of that in C. It will be remembered that in the Miami soils the percentage of accumulation of iron oxide was less than that of alumina. That was the case also in the Podzols of the northeastern part of the United States.

The ba ratio in C is practically the same as in B, but in A_2 it is six times as large as in C and in A_1 nearly nine times as large. This is owing to the very low percentage of alumina in A_1 and A_2, but it shows also that a considerable part of the bases in these two horizons is in combination with the organic matter. Since it is presumably not present in undecomposed silicate minerals it would otherwise have gone out, or down to horizon B with the alumina.

The ba ratio shows that the number of molecules of combined alkalies and alkaline earths in proportion to the number of molecules of alumina decreases with depth from the surface through the B horizon. This shows that some of these substances are present in some other form than in combination with the alumina or, on the other hand, the alumina in B is less rich in them than in A. Presumably practically all the alumina is present as colloid.

The mechanical analysis shows that the quantity of clay in the B horizon is more than twice that in A. The percentage of silt is, however, lower in B than in A. Eluviation, although the soil material is sandy, has affected the very finely divided material, presumably colloidal, mainly.

The composition of a sample of very sandy Norfolk sandy loam from Lexington County, S. C., is shown in Table 61.

TABLE 61.—*Composition of Norfolk sandy loam, Gaston, Lexington County, S. C.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29184	A_1	0- 3	[a]96.47	0.24	0.64	0.80	0.070	0.28	0.10	0.02	0.08	Tr.	0.03	1.50	100.17	0.040	------
			[b]97.93	.24	.65	.81	.070	.28	.10	.02	.08	Tr.	.03	------	100.15	------	------
29185	A_2	3- 6	[a]97.42	.09	.63	.70	.003	.10	.08	Tr.	.14	Tr.	.01	.70	99.87	.020	------
			[b]98.11	.09	.63	.70	.003	.10	.03	Tr.	.14	Tr.	.01	------	99.86	------	------
29186	B	6-48	[a]94.85	.34	1.11	2.02	.010	.10	.11	.25	Tr.	.01	.03	1.20	100.02	.020	------
			[b]95.99	.34	1.12	2.04	.010	.10	.11	.25	Tr.	.01	.03	------	100.00	------	------
29187	C	48-84	[a]86.97	.34	1.91	6.92	.004	.08	.10	.23	Tr.	.02	.05	3.20	99.82	.020	------
			[b]89.85	.35	1.97	7.15	.004	.08	.10	.24	Tr.	.02	.05	------	99.81	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29184	A_1	0- 3	3.1	30.1	28.4	31.3	4.5	0.8	1.8	100.0
29185	A_2	3- 6	2.3	33.9	30.5	27.9	2.4	.8	2.2	100.0
29186	B	6-48	1.4	21.9	19.6	29.1	16.0	4.2	7.6	99.8
29187	C	48-84	1.3	15.4	19.4	30.7	12.5	2.6	18.1	100.0

[1] Collected by J. O. Veatch.
[2] Analyzed by G. J. Hough.
[3] Analyzed by L. T. Alexander.

The percentage of sesquioxides in the B horizon, extending from 6 to 48 inches, is somewhat higher than in A, and the percentage, especially of alumina, in the material below 48 inches, is much higher. The mechanical composition, also, shows a much higher percentage of clay in C than in B. The difference is so great that its origin can not readily be explained as a soil phenomenon. The simplest explanation, confirmed by examination of the sample, is that it is due to the occurrence of a stratum of clay below a depth of 48 inches. This is a geological deposit and different in origin from the heavier B horizon. It is an original condition in the parent material and not the result of soil-profile development. Since this layer constitutes a stratum different in composition from that from which the solum developed, the several ratios and molecular equivalent compositions would present no suggestions regarding what has taken place during soil development. Therefore they have not been calculated.

The Marlboro[18] soils are associated with the Norfolk and have developed, like the Norfolk, from the sandy deposits of the coastal plain. They occupy areas containing many well-defined depressions for which there seems to be no other explanation than that they are the result of collapsing due to solution and removal of underground material, probably calcium carbonate. Carbonate rocks, either consolidated or unconsolidated, do not outcrop in the region, but the soils have a higher content of clay than Norfolk soils.

The composition of a Marlboro profile from Wilson County, N. C., is shown in Table 62.

TABLE 62.—*Composition of Marlboro fine sandy loam, Wilson, Wilson County, N. C.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
32612	A_1	0- 2	[a]86.95	0.96	0.97	2.62	0.01	Tr.	0.18	0.33	1.75	0.13	0.11	5.77	99.78	0.120	------
			[b]92.26	1.02	1.03	2.78	.02	Tr.	.19	.35	1.86	.14	.12	------	99.76	------	------
32613	A_2	2- 8	[a]87.17	1.19	1.69	4.63	.01	Tr.	.19	.34	1.70	.10	.08	3.02	100.12	.030	------
			[b]89.90	1.23	1.74	4.78	.01	Tr.	.20	.35	1.75	.10	.08	------	100.14	------	------
32614	B	8-32	[a]71.78	1.31	5.35	13.73	.01	Tr.	.26	.35	1.67	.08	.14	5.73	100.41	.020	------
			[b]76.08	1.39	5.68	14.57	.01	Tr.	.28	.37	1.77	.08	.15	------	100.38	------	------
32615	C	32-55	[a]71.50	1.31	5.51	14.28	.01	Tr.	.30	.61	1.59	.05	.10	5.85	101.11	.010	------
			[b]75.93	1.39	5.85	15.16	.01	Tr.	.32	.65	1.69	.05	.11	------	101.16	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
32612	A_1	0- 2	1.1	3.4	2.6	40.0	12.2	33.1	7.2	99.6
32613	A_2	2- 8	.8	2.2	1.6	31.5	18.8	32.2	12.3	99.4
32614	B	8-32	.6	1.6	.9	14.0	21.0	25.6	35.6	99.3
32615	C	32-55	1.4	1.4	1.0	12.8	11.2	24.3	47.8	99.9

[1] Collected by W. E. Hearn. [2] Analyzed by G. J. Hough. [3] Analyzed by V. Jacquot.

[18] The Marlboro soils have been included on the soil map with the Orangeburg soils. They are closely associated with the latter since both have developed from coastal-plain deposits containing limestone or marl.

The material lying at the lowest depth sampled constitutes the upper part of the C horizon but contains a much higher percentage of clay than the B horizon. It consists of mottled clay and silt with a low percentage of sand. It is like the Norfolk profile at Lexington, S. C. In the Marlboro sample, however, the heavy stratum lies at less depth than in the Norfolk profile, so that the B horizon has developed from it. The percentage of alumina in B, however, is lower than that in C. The percentage of clay, shown by the mechanical analysis, is more than 10 per cent lower than in C. It does not seem possible, therefore, with the data available, to determine whether alumina and iron oxide have accumulated in B or not. The low percentages of both constituents in A make it extremely probable that both constituents have been lost from this horizon. The percentages of alkalies and alkaline earths are low throughout. Throughout the region of Red and Yellow soils these constituents have been partly leached from the C horizon material to great depths. The A and B horizons are well marked by high silica and low iron oxide and alumina in A_1 and A_2, extending from 0 to 8 inches, and the reverse relationships appear below this.

The absence of lime from all the layers in the profile is noticeable, in view of the probable derivation from calcareous rocks. Soda percentage is unusually high compared with that in the two samples of Norfolk soils described, but the percentage of potash is not high. The alumina is high in both B and C, and the mechanical analysis shows the presence of a high percentage of clay in comparison with the Norfolk and most of the other coastal-plain soils, except the Norfolk from Lexington, S. C., which could have been identified Marlboro as well as Norfolk.

The composition of another set of profile samples from a Marlboro fine sandy loam profile near Bennettsville, S. C., is shown in Table 63. In this case the A and B horizons only were sampled. This soil contains a higher percentage of medium and coarse sand in the A horizon than the Wilson County soil, but, possibly because of this, eluviation seems to have gone further since the percentage of alumina is higher in the B horizon, the percentage of iron oxide being about the same. The percentages of both potash and soda, especially the latter, are lower, but calcium is present in small amounts. The texture horizons are extremely well marked, but since the C horizon was not included it is not certain whether sesquioxides have been merely shifted within, or entirely removed from, the solum.

Table 63.—*Composition of Marlboro fine sandy loam, Bennettsville, S. C.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34744	A_1	0–3	[a]91.71	0.97	0.66	2.88	0.01	0.24	0.19	0.28	Tr.	0.07	0.02	2.97	100.00	0.060	------
			[b]94.51	1.00	.68	2.97	.01	.25	.20	.29	Tr.	.07	.02	------	100.00	------	------
34745	A_2	3–9	[a]93.39	.97	.80	3.91	.01	.19	.20	.18	0.06	.06	.02	.21	100.00	.020	------
			[b]93.56	.97	.80	3.92	.01	.19	.20	.18	.06	.06	.02	------	99.97	------	------
34746	B_1	11–28	[a]70.85	1.05	4.07	16.06	.01	.30	.33	.20	Tr.	.18	.02	6.93	100.00	.020	------
			[b]76.11	1.13	4.37	17.26	.01	.32	.35	.21	Tr.	.19	.02	------	99.97	------	------
34747	B_2	28–36	[a]61.66	1.16	6.17	20.85	.01	.23	.31	.26	Tr.	.21	.02	9.12	100.00	.010	------
			[b]67.88	1.28	6.79	22.94	.01	.25	.34	.29	Tr.	.23	.02	------	100.03	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34744	A_1	0–3	2.2	12.0	12.6	19.6	16.3	28.4	8.7	99.8
34745	A_2	3–9	1.1	10.8	13.0	20.0	16.5	28.0	10.6	100.0
34746	B_1	11–28	1.5	7.1	7.8	12.7	11.1	19.2	40.6	100.0
34747	B_2	28–36	1.4	6.5	6.9	11.6	10.1	16.0	47.3	99.8

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Dec. 8, 1917.
[3] Analyzed by L. T. Alexander.

The composition of samples from an Orangeburg profile, occurring in the vicinity of the Marlboro profile just discussed, is shown in Table 64. The almost complete identity in composition with the associated Marlboro soil is very striking. Not only are the relative percentages similar, but the actual percentages for corresponding substances and horizons are very close together. The two soils have developed from the same kind of material and in the same climatic and vegetative environment. The Marlboro profile has developed on a smooth area, the Orangeburg on a gentle slope but near enough to a small ravine to be thoroughly drained. Oxidation and probably dehydration have been more active than in the Marlboro profile. Eluviation has been more effective, as would be expected, in the Marlboro soil, the separation of the A and B horizons being somewhat sharper and cleaner. The C horizon was not sampled in either case, but each soil is typical of its series. The sa ratios in B_2 for the Marlboro and Orangeburg profiles are 5.03 and 4.5, respectively, and in A_2 are 40.5 and 32.2, respectively, showing in another way the more complete removal of alumina from the A horizon and presumably the greater illuviation or accumulation of the same substance in B in the Orangeburg profile.

Table 64.—*Composition of Orangeburg sandy loam, Bennettsville, S. C.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34740	A_1	0 – 5½	[a]87.08	1.61	0.94	3.65	0.08	0.09	0.01	0.14	0.10	0.01	0.02	6.87	100.00	0.050	------
			[b]93.50	1.08	1.01	3.92	.09	.10	.01	.15	.11	.01	.02	------	100.00	------	------
34741	A_2	5½–12½	[a]89.04	1.46	1.30	4.70	.04	.04	.03	.08	.12	.01	.03	3.15	100.00	.010	------
			[b]91.93	1.51	1.34	4.85	.04	.04	.03	.08	.12	.01	.03	------	99.98	------	------
34742	B_1	12½–24	[a]75.85	1.54	3.65	12.60	.03	.05	.03	.22	.12	.02	.04	5.85	100.00	.010	------
			[b]80.55	1.64	3.88	13.38	.03	.05	.03	.23	.13	.02	.04	------	99.98	------	------
34743	B_2	24 –36	[a]59.20	1.31	6.66	22.06	.03	.04	.05	.28	.12	.03	.01	10.18	100.00	.010	------
			[b]65.89	1.49	7.43	24.54	.03	.04	.05	.31	.13	.03	.01	------	99.96	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34740	A_1	0 – 5½	5.2	21.2	18.3	19.7	10.8	16.7	8.1	100.0
34741	A_2	5½–12½	5.6	19.3	18.1	20.4	10.7	16.2	9.4	99.7
34742	B_1	12½–24	6.3	18.9	15.2	16.6	9.2	6.6	27.1	99.9
34743	B_2	24 –36	5.4	13.2	10.7	12.8	7.0	9.5	41.5	100.1

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Dec. 8, 1917.
[3] Analyzed by L. T. Alexander.

The profile of a soil identified as Norfolk, mainly on the basis of the color of the A and B horizons, from Raiford in Mitchell County, Ga., has been sampled and analyzed. The chemical and mechanical composition are shown in Table 65. An examination of the samples, in the light of the recently acquired knowledge and point of view regarding the Norfolk soils, indicates that the material of the C horizon is better drained than the C horizon of the Norfolk in the Carolinas. Whether or not it be finally identified as a member of the Norfolk or some other related series, there is no question about its membership in the Yellow subgroup of the Red and Yellow soils.

Table 65.—*Composition of Norfolk sandy loam, Raiford, Mitchell County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
30225	A_1	0–7	[a]93.07	0.34	1.10	2.27	0.050	0.60	0.14	0.16	0.24	0.09	0.01	2.07	100.14	0.030	------
			[b]95.03	.35	1.12	2.32	.050	.61	.14	.16	.25	.09	.01	------	100.13	------	------
30226	A_2	8–12	[a]89.44	.44	2.07	4.97	.030	.30	.06	.23	.30	.05	.00	2.46	100.35	.020	------
			[b]91.71	.45	2.12	5.10	.030	.31	.06	.24	.31	.05	.00	------	100.38	------	------
30227	B_1	13–18	[a]83.28	.53	3.20	8.35	.010	.60	.08	.16	.31	.06	.00	3.80	101.38	.020	------
			[b]86.60	.55	3.33	8.68	.010	.62	.08	.17	.32	.06	.00	------	100.42	------	------
30228	B_2	19–30	[a]80.08	.65	4.00	11.35	.005	.36	.08	.20	.31	.05	.02	4.22	101.32	.020	------
			[b]83.61	.68	4.18	11.83	.005	.38	.08	.21	.32	.05	.02	------	101.37	------	------
30229	C_1	31–70	[a]79.85	.71	3.20	10.42	.005	.30	.12	.25	.39	.07	.00	4.54	99.88	.010	------
			[b]83.68	.74	3.35	10.92	.005	.31	.13	.26	.41	.07	.00	------	99.88	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
30225	A_1	0–7	1.6	10.5	15.3	33.0	22.6	8.7	8.2	99.9
30226	A_2	8–12	.9	8.7	13.4	32.3	20.2	8.4	16.2	100.1
30227	B_1	13–18	.6	6.8	11.9	36.4	10.1	8.3	25.7	99.8
30228	B_2	19–30	.9	5.9	9.2	30.3	16.4	7.6	29.6	99.9
30229	C_1	31–70	.9	6.6	8.8	27.9	15.7	8.8	31.2	99.9
30230	C_2	71–82	2.8	13.6	14.2	22.6	11.3	9.5	26.1	100.1

[1] Collected by Mark Baldwin.
[2] Analyzed by G. J. Hough.
[3] Analyzed by A. A. White.

The difference in chemical composition between the A and B horizons is well defined. The upper part only of the C horizon is represented in the chemical composition analysis. The mechanical composition analysis shows the composition of the soil to a depth of 82 inches. The percentage of clay below 70 inches is lower than in the layer from 31 to 70 inches, and the percentages of medium and coarse sand are about twice as high. Horizon B extends from 13 to 30 inches. The layer from 31 to 70 inches is clearly part of the C horizon, according to field evidence.

Both parts of the A horizon have low percentages of sesquioxides, a little less than half as much as in horizon B. The percentages in C are high also. It can not be determined, therefore, whether any actual accumulation has or has not taken place in B, but it is highly probable that it has. There can be little doubt that considerable loss has been suffered by A_1 and A_2.

The percentages of alkalies and alkaline earths are low throughout. That of CaO in the A_1 horizon is higher than in A_2, as is usual in virgin soils throughout the forested part of the United States.

The composition of soil from Greenwood, Mitchell County, Ga., identified as Norfolk sand, is shown in Table 66. To a depth of nearly 6 feet the percentage of alumina is less than 1¼ per cent and that of clay in the mechanical analysis is 3 per cent or less. Below that depth the percentage of alumina is between 4 and 5. The percentage of iron oxide is low also. It is apparent from a study of the profile in place that the sand layer to a depth of 54 inches is the product of the removal of clay originally present, but the underlying material does not seem to have received it. The percentages of alkalies and alkaline earths is very low also.

Table 66.—*Composition of Norfolk sand, Greenwood, Mitchell County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
30219	A_1	0–4	[a]96.09	0.26	0.26	1.22	0.010	(3)	0.06	0.09	0.07	0.01	0.08	1.75	99.90	0.033	------
			[b]97.79	.26	.26	1.24	.010	(3)	.06	.09	.07	.01	.08	------	99.87	------	------
30220	A_2	5–12	[a]97.19	.19	.26	1.19	.010	0.06	(3)	.13	.06	(3)	.11	.81	100.01	.015	------
			[b]97.95	.19	.26	1.20	.010	.06	(3)	.13	.06	(3)	.11	------	99.97	------	------
30221	A_3	13–24	[a]97.32	.26	.26	1.13	.004	.07	(3)	.11	.06	(3)	.08	.60	99.89	.015	------
			[b]97.92	.26	.26	1.14	.004	.07	(3)	.11	.06	(3)	.08	------	99.90	------	------
30222	A_4	24–54	[a]97.38	.26	.29	1.09	.004	.03	(3)	.12	.05	(3)	.08	.98	99.78	.004	------
			[b]97.86	.26	.29	1.10	.004	.03	(3)	.12	.06	(3)	.08	------	99.79	------	------
30223	B	55–84	[a]89.49	.51	1.65	5.53	.004	.07	(3)	.17	.08	.03	.09	2.30	99.92	.009	------
			[b]91.57	.52	1.69	5.66	.004	.07	(3)	.17	.08	.03	.09	------	99.98	------	------
30224	C	85–120	[a]91.41	.48	1.58	4.24	.005	.72	.10	.25	.28	.07	.02	1.95	101.10	.010	------
			[b]93.25	.49	1.61	4.32	.005	.73	.10	.26	.29	.07	.02	------	101.14	------	------

Sample No.	Horizon	Depth	Mechanical[4] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
30219	A_1	0–4	12.4	33.8	17.4	18.9	8.3	5.9	3.3	100.0
30220	A_2	5–12	9.1	32.8	19.3	20.9	9.1	5.1	3.6	99.9
30221	A_3	13–24	8.0	31.5	19.8	22.3	8.9	5.8	3.8	100.1
30222	A^4	24–54	6.9	27.2	20.2	24.9	1.2	15.8	3.7	99.9
30223	B	55–84	13.2	27.1	16.1	18.3	7.3	3.7	14.2	99.9
30224	C	85–120	9.9	28.4	17.8	20.2	7.6	3.4	12.6	99.9

[1] Collected by Mark Baldwin.
[2] Analyzed by G. Edgington and G. J. Hough.
[3] Trace.
[4] Analyzed by A. A. White.

The profile of Norfolk fine sandy loam from near Thomasville, Ga., was sampled to a depth of 12 feet. This is the only Norfolk profile yet discussed in which an important thickness of the C horizon has been included. The chemical and mechanical composition of material from the profile are shown in Table 67. The profile consists of a 6-inch sandy A_1 horizon containing enough organic matter to stain it dark, a pale-yellow A_2 horizon extending to 18 inches, and a yellow or greenish-yellow heavier, or sandy clay, horizon extending to a depth of 48 inches. This is underlain

by a red horizon extending to a depth of 6 feet, which on field inspection seems to be lighter in texture than the overlying horizon, but the mechanical analysis shows that it contains little more than half as much fine sand and very fine sand as the overlying horizon, and the same percentage of clay. This is clearly part of horizon B.

TABLE 67.—*Composition of Norfolk fine sandy loam, Thomasville, Ga.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29127	A_1	0–6	a 91.74	0.44	0.64	1.93	0.009	0.32	0.08	[3]	0.05	[3]	0.05	4.73	99.99	0.080	------
			b 96.28	.46	.67	2.03	.009	.34	.08	[3]	.05	[3]	.05	------	99.97	------	------
29128	A_2	6–18	a 92.48	.80	1.45	2.87	.006	.40	.16	0.11	.52	0.04	.02	1.94	100.80	.024	------
			b 94.31	.82	1.48	2.93	.006	.41	.16	.11	.53	.04	.02	------	100.82	------	------
29129	B_1	18–48	a 82.98	.64	2.91	9.20	.004	.30	.16	.03	.04	.03	.03	4.03	100.35	.030	------
			b 86.41	.67	3.03	9.51	.004	.31	.17	.03	.04	.03	.03	------	100.30	------	------
29130	B_2	48–72	a 61.94	.44	14.53	14.47	[3]	.14	.10	.05	.04	.15	.08	7.65	99.59	.009	------
			b 67.08	.48	15.73	15.67	[3]	.15	.11	.05	.04	.16	.09	------	99.56	------	------
29131	C	72–144	a 74.12	6.91	3.42	15.40	.008	.10	.20	.30	.51	.07	.05	5.80	100.88	.050	------
			b 78.67	7.33	3.63	16.34	.008	.11	.21	.32	.54	.07	.05	------	100.92	------	------

Sample No.	Horizon	Depth	Mechanical[4] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29128	A_2	6–18	0.1	1.5	4.1	50.2	28.6	8.2	7.3	100.0
29129	B_1	18–48	.2	1.1	3.4	42.8	20.5	6.7	25.3	100.0
29130	B_2	48–72	12.7	11.7	5.9	23.7	10.8	9.9	25.4	100.1
29131	C	72–144	.0	.1	.2	21.6	32.1	10.6	35.4	100.1

[1] Collected by J. O. Veatch.
[2] Analyzed by G. J. Hough, S. Mattson, and G. Edgington.
[3] Trace.
[4] Analyzed by L. T. Alexander.

The chemical composition table shows the presence in the B_2 horizon of a percentage of alumina more than 50 per cent higher than in the overlying horizon, and that of iron oxide is five times higher, but the percentage of clay by the mechanical analysis is the same in both. From 6 to 12 feet the material consists of highly variegated or "mottled" sandy clay with a higher percentage of clay than that of any horizon above. The percentage of iron oxide is much lower.

The top of the variegated horizon corresponds possibly to the level of permanent ground water. The reddish layer seems to be present just above the mottled zone of the Norfolk soils over a wide area, but it is usually only a few inches thick. Its significance is not entirely clear, but by analogy with soils developing under similar relationship to ground water, especially in the Tropics, it seems possible that it may be interpreted as a horizon formerly occupied by ground water but below which the permanent level of ground water has, at a relatively recent date, sunk, due to the progressive development of the topographic cycle. When ground water stood higher, iron was accumulated at its top as hydrous oxide. Since the lowering of the ground water level, more complete oxidation with probably some dehydration has produced the reddish color. That it was formerly somewhat like, if not identical with, the mottled zone is indicated by the presence in the reddish mass of rather soft iron-oxide segregations, or imperfect concretions, similar to those in the mottled layer.

If this be its origin, it can not be an illuviated horizon, and the presence of the typical Norfolk B horizon between 18 and 48 inches shows that the red horizon is not part of the normal B horizon, but at the same time it can not be considered a typical C horizon. It is more like B than C. It has a strikingly close resemblance to the "iron crust" of Laterite as described in standard works on geology.

Recent work in the Tropics by members of the staff of the United States Soil Survey indicate very strongly that the lateritic iron crust, being a ground water horizon as has been shown by Campbell (*3*), has no necessary connection with Laterites. If and when developed in a Laterite the excess of iron oxide in the horizon, as shown by Harrassowitz (*8*), has come from below. There seems to be no reason why it should not have its source in the overlying horizon also if the soil profile be podzolic. In the Thomasville soil the low content of iron oxide in the mottled zone below a depth of 6 feet, strongly suggests that some of the iron for the accumulation zone has come from below and that the same process has been active here as in the ground-water Laterites. The podzolic character of the solum suggests the possibility of an overlying source also for some of it, but the fact so abundantly demonstrated by chemical analyses in this report that the podzolic iron oxide may be removed entirely from the soil makes the apparent support of this possibility, by reason of the low content of iron in the solum, doubtful. It seems to have suffered more loss of sesquioxides than to have profited by illuviation. The percentage of alumina increases downward.

The comparatively slight extent of profile development even in soil material where eluviation would seem to be rapid, suggests that its lack in these two samples is due, possibly, to the "subserial" development of this Norfolk soil (*18*). This possible development, not on an old surface like that on which the Tifton soils have developed but on a new surface recently exposed by erosion, may explain the slight profile development. Some profile development has taken place, the profile being of exactly the same podzolic type as that of the Tifton soils.

The suggestion is based on preliminary studies of the last year or two. The possibility that the Carolina Norfolk soil may be somewhat different from that of Georgia is a recently acquired point of view, and sufficient time has not yet elapsed to determine whether this is confirmed by the prevailing characteristics of the Georgia Norfolk soil. From the practical point of view the differences supposed to exist are wholly unimportant.

In respect to the other features of the profile, such as the very low percentage of alkalies and alkaline earths and high percentage of silica present, this soil is like the Norfolk soils already described.

The composition of the colloid in the Norfolk soils of Georgia has not been determined by the American method of extracting the colloid and analyzing it. No attempt has been made to determine its composition by digestion with HCl and an analysis of the dissolved portion, the method used rather extensively in Europe. The percentage of Fe_2O_3 and Al_2O_3 soluble in HCl (sp. gr. 1.12) after digestion is shown in the data presented in the Norfolk profile in Table 68. The percentage of soluble iron oxide is high throughout, that in B being entirely soluble. The percentage of soluble alumina is less high than of iron oxide, but in the B horizon much more than half of it is soluble. In both iron oxide and alumina the solubility is lower in horizon C than in B.

TABLE 68.—*Fe_2O_3 and Al_2O_3 dissolved in HCl (sp. gr. 1.12) digested for 10 hours on steam bath*[1]

Sample No.	Horizon	Depth	Fe₂O₃ Quantity soluble	Fe₂O₃ Quantity present	Fe₂O₃ Percentage of substance soluble	Al₂O₃ Quantity soluble	Al₂O₃ Quantity present	Al₂O₃ Percentage of substance soluble
NORFOLK FINE SANDY LOAM, THOMASVILLE, GA.								
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29128	A_2	6–18	0.65	1.48	44	1.69	2.93	57
29129	B_1	18–48	2.85	3.03	94	7.02	9.58	73
29130	B_2	48–72	15.29	15.73	97	9.95	15.67	63
29131	C	72–180	2.30	3.63	63	6.91	16.34	42
COLLINGTON LOAM, PRINCE GEORGES COUNTY, MD.								
29677	A_1	1–12	2.49	2.96	84	1.23	4.75	27
29678	A_2	13–18	3.52	4.36	80	1.53	3.60	42
29679	B	18–40	7.98	9.73	82	2.52	5.36	47
29680, 29681	C	40–50	10.35	12.50	83	2.48	3.14	78
A PODZOL, CLOQUET, MINN.								
321426	1	0–2	1.48	2.37	62	1.72	8.83	19
321427	2	3–8	3.53	4.48	79	2.57	9.61	26
321428	3	9–14	4.58	5.32	82	3.44	11.16	30
321429	4	15–36	4.82	------	------	3.69	------	------

[1] Analysis by G. Edgington. Percentages calculated on weight of sample dried at 110° C.

The significance of these figures becomes clear when they are compared with those obtained by treating soils of the other great groups in the same way. Only one result from a Gray-Brown Podzolic soil and one from a Podzol are available. The result from the Gray-Brown Podzolic soil was obtained from Collington loam, a coastal-plain soil. Results obtained from soils from residual material in both the Gray-Brown Podzolic region and that of the Red and Yellow soils, such as the Chester from the former and the Cecil from the latter, would have been better but they are not available. Table 68 shows that the solubility of iron oxide in the Collington sample is high, but that not all was dissolved. In this soil (a loam) the percentage of soluble iron oxide was almost uniformly the same throughout the profile. The percentage of soluble alumina is less than that in the Norfolk soil. The Norfolk soil was sampled to greater depth than the Collington, and in the deepest layer the solubility of alumina is less than in the deepest layer of the Collington soil sampled. At comparable depths, down to 40 inches, the solubility in the Norfolk soil is highest. The solubility of both constituents in the Podzol is low and that of alumina very low. That of the iron oxide in horizon B is about the same as in the corresponding horizon of Collington loam.

A sample of Norfolk sandy loam from Dothan, Houston County, Ala., in the southeast corner of the State, the composition of which is shown in Table 69, shows essentially the same type of profile and degree of development as the samples from Georgia. The percentages of alkalies and alkaline earths are low, being but little above a trace. This sample shows the usual features of the Norfolk profile without specific evidence of the accumulation of clay in the B horizon but clear evidence of its removal from A.

TABLE 69.—*Composition of Norfolk sandy loam, Dothan, Houston County, Ala.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
32333	A_1	0–6	a 91.23	0.40	0.48	3.81	0.015	Tr.	Tr.	0.10	0.15	0.02	0.02	3.88	100.11	0.025	------
			b 94.90	.42	.50	3.96	.016	Tr.	Tr.	.10	.16	.02	.02	------	100.10	------	------
32334	A_2	7–10	a 91.94	.43	.58	4.65	.012	Tr.	Tr.	.08	.17	.02	.03	2.56	100.47	.002	------
			b 94.33	.44	.60	4.77	.012	Tr.	Tr.	.08	.17	.02	.03	------	100.45	------	------
32335-6	B_1	11–37	a 85.18	.60	1.14	9.06	.008	Tr.	Tr.	.13	.19	.01	.03	3.65	100.00	.008	------
			b 88.38	.62	1.18	9.40	.008	Tr.	Tr.	.13	.20	.01	.03	------	99.96	------	------
32337	B_2	38–49	a 82.06	.56	1.17	11.58	.003	Tr.	Tr.	.09	.17	.01	.05	4.26	99.95	.004	------
			b 85.69	.58	1.22	12.09	.003	Tr.	Tr.	.09	.18	.01	.05	------	99.91	------	------
32338	C	50–80	a 81.96	.66	1.25	11.67	.008	Tr.	Tr.	.09	.16	.02	.02	4.17	100.01	.002	------
			b 85.50	.69	1.30	12.17	.008	Tr.	Tr.	.09	.17	.02	.02	------	99.97	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
32333	A_1	0–6	2.6	14.9	19.1	31.3	13.4	8.8	9.8	99.9
32334	A_2	7–10	2.4	12.3	18.1	34.1	11.6	8.4	13.2	100.1
32335-6	B_1	11–37	3.3	12.8	16.1	26.8	9.9	7.1	23.8	99.8
32337	B_2	38–49	1.9	13.9	20.6	25.6	4.9	2.5	30.6	100.0
32338	C	50–80	2.3	10.4	12.4	25.7	12.1	5.9	31.3	100.1

[1] Collected by Mark Baldwin and E. D. Fowler.
[2] Analyzed by G. Edgington.
[3] Analyzed by L. T. Alexander.

The general characteristics of the soils of the Tifton series, described on page 41, ally them to the Norfolk soils. They are closely associated with the latter in Georgia. Such studies as have been carried on indicate that they are closely related in character and origin to what have been defined here as true Norfolk soils, such as those of the Carolinas. They seem to have passed through a Norfolk stage in their development, their most striking characteristics being due, apparently, to having passed to a more advanced stage of development than that represented by the true Norfolk soils.

The composition of samples from a profile of Tifton fine sandy loam from Carnegie, Randolph County, Ga., is shown in Table 70. The A horizon is 10 inches thick, the B extends from 10 to 48 inches, and the C lies below this depth. The relative percentages of silica and the sesquioxides in the A and B horizons show the usual relationships found in podzolic profiles. The A_1 horizon contains a little less than 3 per cent of organic matter, the percentages of sesquioxides are low, and of silica high. B_1 contains about 2 per cent of organic matter, more than that contained in A_2, an accumulation of organic matter very rare in the Gray-Brown Podzolic or in the Red and Yellow soils but characteristic of the Podzols.

TABLE 70.—*Composition of Tifton fine sandy loam, Carnegie, Randolph County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
32300	A_1	0–3	[a]86.88	0.35	0.93	3.18	0.040	0.12	0.01	Tr.	0.34	0.10	0.23	7.39	99.57	0.136	------
			[b]93.80	.38	1.00	3.43	.050	.13	.01	Tr.	.37	.11	.24	------	99.52	------	------
32301	A_2	4–10	[a]91.76	.40	.92	3.50	.032	Tr.	.06	Tr.	.30	.06	.05	2.53	99.61	.028	------
			[b]94.13	.41	.94	3.59	.033	Tr.	.06	Tr.	.31	.06	.05	------	99.58	------	------
32302	B_1	11–32	[a]64.45	1.02	5.51	20.28	.004	.20	.13	0.44	.35	.11	.07	8.87	101.43	.100	------
			[b]70.70	1.12	6.04	22.22	.004	.22	.14	.48	.38	.12	.08	------	101.50	------	------
32303	B_2	33–48	[a]64.44	1.19	5.67	20.08	.004	.18	.08	.42	.44	.16	.05	8.40	101.11	.008	------
			[b]70.35	1.30	6.19	21.91	.004	.20	.09	.46	.48	.17	.05	------	101.20	------	------
32304	C	49–60	[a]66.64	1.02	7.60	17.01	.004	.20	.07	.39	.42	.17	.10	7.15	100.77	.002	------
			[b]71.75	1.10	8.18	18.32	.004	.22	.08	.42	.45	.18	.11	------	100.81	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
32300	A_1	0–3	2.4	8.5	7.3	40.6	17.4	10.1	13.7	100.0
32302	B_1	11–32	1.0	4.0	3.5	18.7	11.0	21.4	40.4	100.0
32303	B_2	33–48	.9	5.6	4.2	18.7	10.7	11.3	48.5	99.9
32304	C	49–60	1.2	7.2	5.3	21.9	10.9	9.4	44.2	100.1

[1] Collected by Mark Baldwin and E. D. Fowler.
[2] Analyzed by G. J. Hough.
[3] Analyzed by J. B. Spencer.

The percentage of alumina in B_1 is very high compared with that in A and higher than in C. The percentage of iron oxide is highest in C. This is a feature characteristic of the usual chemical analysis of Tifton soils, not appearing in other soils as a constant relationship. If all the iron oxide in the A and B horizons were determined, however, this would not be the case even in the Tifton soils.

The iron oxide in the horizons of Tifton soils is present in comparatively large quantities, however, but a large part of it is present in the form of indurated bodies, consisting of fragments of clay ironstone in part but containing some concretions. In preparing the sample for chemical analysis these bodies are usually sifted out as "gravel." In the C horizon these bodies are usually not indurated, so that in preparing the samples for analysis they are crushed in the mortar and no material is lost by sifting.

No conclusions can be drawn, therefore, from the usual analyses regarding the accumulation of iron oxide in the B horizon over that in C. The actual content of iron oxide, including that in the indurated bodies in both the B and C horizons, has been shown by Fowler (*5*).

According to analyses made by Edgington, in the laboratories of the Bureau of Chemistry and Soils, of samples collected by Fowler, the actual percentage of iron oxide in the B horizon of a typical Tifton fine sandy loam is 23.62 and that in the C horizon between depths of 46 and 110 inches is a little less than 4.5 per cent.

The percentage of alkalies and alkaline earths is low, and that of P_2O_5 is low but not proportionally so.

The several ratios and the molecular equivalent composition in SiO_2, Fe_2O_3, Al_2O_3 and the total alkalies and alkaline earths are shown in Table 71.

TABLE 71.—*Tifton fine sandy loam, Carnegie, Randolph County, Ga.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
32301	A_2	4–10	44.60	265.36	0.1421	15.5	0.0058	0.035	0.0050
32302	B_1	11–32	5.41	31.20	.0690	11.7	.0378	.217	.0148
32304	C	49–60	6.66	23.24	.0870	11.9	.0512	.180	.0153

Since an important part of the iron oxide of the A and B horizons was not included, the sf ratios, or the relative molecular composition in iron oxide, are not significant.

The molecular proportions of silica in the B_1 and C horizons are nearly the same, the number in C being less than 2 per cent larger, but the number in A increases because of the high quartz content. The same relationship of B and C in SiO_2 was found in the Norfolk. This is to be expected because of the absence of decomposable silicates in the material. The proportional molecular content of alumina in B_1 is 20 per cent higher than in C. Since the content of feldspar here, as in the coastal-plain deposits elsewhere, is practically nil, this increase must be ascribed to illuviation. The number in A_2 is only 20 per cent of the number in C, an apparent loss of 80 per cent. The proportional loss from A is greater than the gain in B, but the thickness of B_1 and B_2 combined, both of which are similar in composition, is nearly four times as great as the combined A. A possible change in volume of A makes any conclusion as to a loss from the profile as a whole, doubtful.

Notwithstanding a greater amount of alumina in B_1 than in C the proportional number of molecules of all alkalies and alkaline earths is slightly less in B_1 than in C, but the number in A is much smaller, probably owing to eluviation rather than to leaching.

The composition of a profile of Tifton sandy loam from Ocilla, Irwin County, Ga., is shown in Table 72. The soil is typical well-developed Tifton with a C horizon, showing an apparent accumulation of both iron oxide and alumina in horizon B. The percentages of these constituents in A_1 and A_2 are low, and those of the alkalies and alkaline earths are very low throughout, that of CaO constituting merely a trace. Nothing in the composition table or in the natural profile suggests any significant difference in character of the original geological material between the surface and the bottom of the profile, a depth of about 6 feet.

TABLE 72.—*Composition of Tifton sandy loam, Ocilla, Irwin County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. c*	*P. ct.*	*P. ct.*
32340	A_1	3–10	[a]92.09	0.44	1.15	3.71	0.029	Tr	Tr	0.15	0.17	0.01	0.03	2.06	99.84	0.014	------
			[b]94.01	.45	1.17	3.79	.030	Tr	Tr	.15	.17	.01	.03	------	99.81	------	------
32341	A_2	11–22	[a]79.67	.57	3.47	11.39	.010	Tr	0.11	.13	.21	Tr	.01	4.77	100.34	.019	------
			[b]83.66	.60	3.64	11.97	.010	Tr	.12	.14	.22	Tr	.01	------	100.37	------	------
32342	A_3	22–36	[a]73.40	.68	4.93	14.70	.013	Tr	.12	.17	.14	.01	.09	6.15	100.40	.021	------
			[b]78.29	.72	5.23	15.67	.014	Tr	.13	.18	.15	.01	.10	------	100.49	------	------
32343	B	37–54	[a]52.14	1.34	9.92	25.24	Tr	Tr	.12	.55	.32	.16	.10	10.65	100.54	.006	------
			[b]58.37	1.50	11.10	28.25	Tr	Tr	.13	.62	.36	.18	.11	------	100.62	------	------
32344	C	55–70	[a]62.36	1.01	8.97	19.45	.008	Tr	.06	.57	.38	.10	.07	7.77	100.74	.000	------
			[b]67.61	1.09	9.72	21.08	.009	Tr	.07	.62	.41	.11	.08	------	100.80	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
32340	A_1	3–10	4.1	18.6	9.0	24.4	4.4	32.2	7.0	99.7
32341	A_2	11–22	2.3	13.7	8.6	20.3	4.6	26.6	23.8	99.9
32342	A_3	22–36	1.6	10.8	5.8	15.4	6.3	23.7	36.4	100.0
32343	B	37–54	.4	3.9	2.6	6.6	3.0	25.7	57.7	99.9
32344	C	55–70	2.6	6.2	3.4	14.8	10.0	18.6	44.5	100.1

[1] Collected by Mark Baldwin and E. D. Fowler.
[2] Analyzed by G. Edgington and G. J. Hough.
[3] Analyzed by J. B. Spencer.

The several ratios and molecular equivalent composition are shown in Table 73.

TABLE 73.—*Tifton sandy loam, Ocilla, Irwin County, Ga.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
32341	A_2	11–22	11.88	60.08	0.036	1.387	0.0221	0.1171
32343	B	37–54	3.51	13.93	.045	.968	.0695	.2763
32344	C	55–70	5.45	18.42	.064	1.120	.0608	.2062

The sa ratios show well-defined accumulation of alumina in B if the parent material is uniform throughout the profile. Assuming no higher percentage of silica in the geological material of B than of C, alumina has accumulated to about 30 per cent more than is present in C. The amount in A is very small as is shown by the complete analysis. Iron oxide has increased in B also, but the percentage of increase is not so great as that of alumina. The total amount present in both B and C is large.

The composition of material from a profile of Tifton sandy loam from Ellenton in Colquitt County, Ga., in which the upper part of the A horizon was not analyzed, is shown in Table 74.

TABLE 74.—*Composition of Tifton sandy loam, Ellenton, Colquitt County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34035	A	6–26	[a]89.78	0.44	3.36	3.46	0.004	0.16	0.00	0.06	0.18	0.03	0.01	1.97	99.45	0.008	------
			[b]91.58	.45	3.43	3.53	.004	.16	.00	.06	.18	.03	.01	------	99.42	------	------
34036	B	26–42	[a]77.88	.71	7.01	9.46	Tr.	.28	.12	.04	.16	.05	.00	4.32	100.03	.014	------
			[b]81.40	.74	7.33	9.88	Tr.	.29	.13	.04	.17	.05	.00	------	100.03	------	------
34038	C	52–80	[a]83.53	.62	2.09	9.40	Tr.	.52	.01	.01	.03	.03	.00	3.65	99.89	.006	------
			[b]86.70	.64	2.17	9.75	Tr.	.54	.01	.01	.03	.03	.00	------	99.84	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34035	A	6–26	6.1	19.7	20.5	26.5	12.5	7.5	7.2	100.0
34036	B	26–42	8.8	16.5	15.0	20.0	9.8	5.1	24.8	100.0
34038	C	52–80	3.6	25.3	26.6	12.1	3.3	3.5	25.6	100.0

[1] Collected by E. D. Fowler.
[2] Analyzed by G. J. Hough.
[3] Analyzed by L. T. Alexander.

This soil is identified as a deep phase of the sandy loam, the phase designation referring to the thick 26-inch A horizon containing only 3.5 per cent of alumina and about the same percentage of iron oxide. The percentage of iron oxide in C is only a third that in B. That in B is high, partly because in this sample the total iron, including that in the concretions, was determined. The percentage in C below the upper foot or two is lower than in the upper part, which is a zone of concentration, and as profile development moves downward and the upper part of any preexisting C horizon becomes incorporated in the lower part of B, the latter acquires an excess of iron oxide. The layer in the Colquitt County sample, extending from 52 to 80 inches, passes into the C horizon below the zone of iron oxide concentration.

The percentage of alumina in A is low. Those in B and C are almost the same, but moderately high. The B horizon in this soil, with a high percentage and an evident accumulation of iron oxide and a moderate percentage of alumina without an apparent accumulation, is like the sample of Tifton soil from Carnegie, Ga., and those samples of the Norfolk soils in which the presence of material from horizon C allowed a comparison between B and C.

The percentages of alkalies and alkaline earths are all extremely low, in harmony with the yellow sandy soils generally.

The composition of material from a profile of Tifton sandy loam more sandy than the profiles already examined is shown in Table 75.

TABLE 75.—*Composition of Tifton sandy loam, Meigs, Ga.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
30231	A_1	0–4	[a]91.81	0.38	1.12	1.98	0.016	0.34	0.16	0.15	0.19	0.03	0.04	4.47	100.68	0.100	------
			[b]96.11	.40	1.17	2.07	.017	.36	.17	.16	.20	.03	.04	------	100.73	------	------
30232	A_2	5–11	[a]94.01	.38	1.43	2.80	.006	.30	.08	.16	.10	.02	.02	1.62	100.92	.020	------
			[b]95.58	.39	1.45	2.85	.006	.30	.08	.16	.10	.02	.02	------	100.96	------	------
30233	B_1	12–18	[a]79.11	.60	3.04	11.77	.005	.40	.13	.16	.24	.04	.04	4.00	99.53	.030	------
			[b]82.41	.62	3.17	12.26	.005	.42	.14	.17	.25	.04	.04	------	99.53	------	------
30234	B_2	19–33	[a]77.26	.72	4.50	12.27	.005	.34	.18	.20	.30	.07	.03	5.60	101.47	.034	------
			[b]81.82	.76	4.76	12.99	.005	.36	.19	.21	.32	.07	.03	------	101.52	------	------
30235	C	34–39	[a]76.94	.66	5.77	11.64	.003	.36	.11	.19	.24	.08	.06	5.18	101.23	.020	------
			[b]81.12	.70	6.08	12.27	.003	.38	.12	.20	.25	.08	.06	------	101.26	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
30231	A_1	0–4	10.5	25.1	18.3	19.9	11.6	7.4	7.0	99.8
30232	A_2	5–11	6.6	24.4	17.8	21.6	12.5	7.9	9.2	100.0
30233	B_1	12–18	6.1	19.0	14.8	19.1	10.7	7.3	23.0	100.0
30234	B_2	19–33	12.5	22.2	12.4	12.0	6.3	4.5	30.1	100.0
30235	C	34–39	3.7	16.4	12.8	15.1	9.5	6.1	36.2	99.8

[1] Collected by Mark Baldwin. [2] Analyzed by G. J. Hough. [3] Analyzed by L. T. Alexander.

The high percentage of iron oxide in the horizon designated as C suggests that only the top of this horizon has been reached. As will be shown the iron oxide in horizon C of the Tifton soils is lower than that in B, but it has already been stated that the total amount of this constituent in the B horizon of these soils is not shown, though that in C is all shown, as a rule, since it is not present in the form of hard pellets or fragments. In this sample, the top of horizon C, where the iron oxide had accumulated at the level of the (theoretical) ancient ground water level but had not yet been brought near enough to the surface by erosion to cause consolidation or induration, a large part of the iron oxide was crushed and analyzed. The hardened fragments in horizon B, however, were discarded as "gravel." The percentages of alumina in B and C are almost identical.

Horizon A has lost heavily of alumina and of iron oxide. Alkalies and alkaline earths are present in the usual small percentages.

The mechanical analysis table shows a higher percentage of clay in C than in B.

In some analyses made to determine the total amount of iron oxide in Tifton soils, including that in the concretions and fragments, the percentage in the B horizon of a sample from Mitchell County, Ga., was 23.6, and the total percentage in C ranged a little above 3. In another sample from the same county the percentage in B was 6.9, and that in C was 4.4.

The general features of the soils of Florida have been described on page 42. The composition of samples of Norfolk fine sand from a profile at Dade City on the western side of the central Florida sandy ridge is shown in Table 76. No discussion is necessary. The chemical and mechanical composition are consistent, showing a low percentage of all constituents except sand.

TABLE 76.—*Composition of Norfolk fine sand, Dade City, Fla.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29060	A	0–10	[a]91.49	0.50	1.75	4.51	0.007	0.01	0.02	0.16	Tr.	0.05	0.05	1.83	100.37	0.020	------
			[b]93.19	.51	1.78	4.59	.007	.01	.02	.16	Tr.	.05	.05	------	100.37	------	------
29061	B_1	10–20	[a]92.37	.22	.64	2.92	.006	.20	Tr.	.16	Tr.	1.20	.03	2.56	100.31	.020	------
			[b]94.79	.23	.66	3.00	.006	.20	Tr.	.16	Tr.	1.23	.03	------	100.36	------	------
29062	B_2	20–60	[a]92.86	.27	.67	2.90	.006	.11	Tr.	.07	0.06	.86	.06	2.19	100.06	.020	------
			[b]94.92	.28	.68	2.96	.006	.11	Tr.	.07	.06	.89	.06	------	100.04	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Tota mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29060	A	0–10	0.1	3.4	7.4	75.2	5.8	1.8	6.4	100.1
29061	B_1	10–20	.3	2.6	6.7	71.6	10.2	2.1	6.4	99.9
29062	B_2	20–60	.2	4.0	9.6	76.6	3.6	1.8	4.2	100.0

[1] Collected by J. O. Veatch.
[2] Analyzed by G. Edgington, S. Mattson, and I. A. Denison.
[3] Analyzed by A. A. White.

Another sample of what has been mapped as Norfolk fine sand from Flagler County, Fla. (Table 77), contains only 2 per cent of alumina and less than 1 per cent of iron oxide.

TABLE 77.—*Composition of Norfolk fine sand, Ocean City, Flagler County, Fla.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
30197	A_1	0–2	[a]95.19	0.74	0.58	1.37	0.028	0.02	0.01	0.16	0.21	0.01	0.04	1.55	99.91	0.043	------
			[b]96.66	.75	.59	1.39	.028	.02	.01	.16	.21	.01	.04	------	99.87	------	------
30198	A_2	3–7	[a]96.68	.67	.55	1.37	.016	.16	Tr.	.14	.21	Tr.	.04	.37	100.21	.009	------
			[b]97.04	.67	.55	1.37	.016	.16	Tr.	.14	.21	Tr.	.04	------	100.20	------	------
30199	B_1	8–22	[a]94.79	.68	.80	1.94	.017	.17	Tr.	.18	.22	.13	.04	.92	99.89	.027	------
			[b]95.67	.69	.81	1.96	.017	.17	Tr.	.18	.22	.13	.04	------	99.89	------	------
30200	B_2	23–32	[a]95.32	.67	.74	2.02	.016	.15	Tr.	.16	.22	.08	.03	.67	100.08	.009	------
			[b]95.94	.67	.74	2.03	.016	.15	Tr.	.16	.22	.08	.03	------	100.04	------	------
30201	C	33–54	[a]95.04	.72	.73	1.98	.017	.17	Tr.	.19	.20	.07	.02	.59	99.73	.007	------
			[b]95.59	.72	.73	1.99	.017	.17	Tr.	.19	.20	.07	.02	------	99.70	------	------

[1] Collected by Mark Baldwin. [2] Analyzed by G. Edgington.

TABLE 77.—*Composition of Norfolk fine sand, Ocean City, Flagler County, Fla.*—Continued.

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
30197	A_1	0–2	0.3	1.4	5.7	86.8	3.3	1.0	1.5	100.0
30198	A_2	3–7	0	1.1	4.6	86.8	5.3	.7	1.5	100.0
30199	B_1	8–22	0	.9	4.5	86.0	4.7	.9	2.9	99.9
30200	B_2	23–32	.1	.8	3.5	86.6	5.4	.4	3.1	99.9
30201	C	33–54	0	1.0	3.8	85.8	5.9	.8	2.5	99.8

[3] Analyzed by L. T. Alexander.

A sample of Dade fine sandy loam from 6 miles east of Naples, Collier County, Fla., has the general physical characteristics of the Norfolk soils but has developed from sandy calcareous material. The material between depths of 30 and 40 inches effervesces freely in hydrochloric acid. In other respects it is Norfolk sand, of the Florida phase of that series. The composition is shown in Table 78.

TABLE 78.—*Composition of Dade fine sandy loam, Naples, Collier County, Fla.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28556	A_1	0–3	[a]98.08	0.14	0.07	0.42	0.003	0.17	0.040	0.10	0.05	0.01	0.05	1.09	100.22	0.030	------
			[b]99.16	.14	.07	.43	.003	.17	.040	.10	.05	.01	.05	------	100.19	------	------
28557	A_2	3–30	[a]96.80	.66	.64	.86	.003	.20	.004	.12	.15	.05	.07	.50	100.05	.000	------
			[b]97.23	.66	.64	.86	.003	.20	.004	.12	.15	.05	.07	------	100.01	------	------
28558	B	30–40	[a]93.05	.16	1.67	1.37	.003	1.94	.030	.11	.03	.01	.01	2.11	100.49	.020	------
			[b]95.05	.16	1.71	1.40	.003	1.98	.030	.11	.03	.01	.01	------	100.51	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28556	A_1	0–3	0.2	4.4	9.4	83.6	1.6	0.7	0.3	100.2
28557	A_2	3–30	.1	6.6	10.2	79.8	2.6	.2	.4	99.9
28558	B	30–40	.2	5.6	9.2	75.4	3.0	2.2	4.4	100.0

[1] Collected by J. O. Veatch.
[2] Analyzed by R. S. Holmes, G. Edgington, and S. Mattson.
[3] Analyzed by A. A. White.

COMPOSITION OF ORANGEBURG AND GREENVILLE SOILS

The composition of a profile of an Orangeburg sandy loam from Bennettsville, S. C., was discussed briefly on page 48. The Red soils of the coastal plain, of which the Orangeburg is one of the most characteristic, occur to only a very slight extent in the Carolinas. In Georgia typical Orangeburg soils occur in large areas and in characteristic development. Their distribution and geographic relationships have already been described.

Several series of soils belonging to the Orangeburg group have been differentiated. The two principal members are the Orangeburg and Greenville series. The former consists of soils from rather sandy material in which a profile seemingly normal to the environment has developed, consisting of a light-colored very sandy A horizon and a heavier, usually sandy clay, bright-red B horizon, which is underlain by reddish well-drained material lighter in texture than that in B. The chemical composition of material from the A and B horizons of a profile from Lauderdale County, Miss., together with that of colloid extracted from the B horizon, is shown in Table 79. The percentage of iron oxide even in B is low, but the color is red. Alumina is low throughout but considerably higher in B than in A. The percentage of alkalies and alkaline earths is low throughout. The percentage of colloid extracted by the method employed is nearly four times as much in B as in A. The sa ratio in the colloid is almost exactly 2, indicating that the lateritic stage of elimination of silicate silica has almost been reached.

TABLE 79.—*Chemical composition of Orangeburg fine sandy loam, Lauderdale County, Miss.*[1] [2]

Horizon	Depth	SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	0–10	[a]93.66	0.50	0.93	2.57	0.64	0.16	0.06	0.45	0.15	0.03	0.09	1.53	100.77	0.030	------
		[b]95.11	.50	.94	2.60	.64	.16	.06	.45	.15	.03	.09	------	100.73	------	------
B	10–36	[a]87.61	.52	2.41	6.30	.266	.26	.14	.37	.35	.08	.03	2.48	100.82	.030	------
		[b]89.84	.53	2.47	6.45	.272	.27	.14	.38	.35	.08	.03	------	100.81	------	------
		[c]40.35	.44	10.08	33.27	.595	.45	.67	.81	.29	.17	.09	13.60	100.91	.250	------
		[d]46.70	.51	11.66	38.50	.680	.52	.72	.94	.33	.20	.10	------	100.80	------	------

[1] Collected by H. H. Bennett.
[2] Analyzed by W. O. Robinson and R. S. Holmes.

Greenville soils, the red to reddish soils associated with the Orangeburg, and derived from less sandy but otherwise similar material, have developed from calcareous rocks, are intimately associated geographically with the Orangeburg soils, and may be considered equivalents of the latter in which no light-colored, or at least no gray, highly sandy A horizon has yet been formed. The composition of a sample of Greenville sandy loam from Evergreen, Ala., in which the process of podolization has attained a stage of development intermediate between that of the true Greenville and that of the Orangeburg, is shown in Table 80. The A horizon is rich brown rather than gray as in the Orangeburg soils, and the percentage of iron oxide is less than half that in B. The high percentage of iron oxide in C_1 is caused by the presence of iron concretions which were included. The layer between depths of 4 and 48 inches is deep red and relatively heavy as shown by the mechanical analysis, and the C horizons are reddish yellow. The percentages of alkalies and alkaline earths are all very low, but that of manganese is high.

TABLE 80.—*Composition of Greenville sandy loam, Evergreen, Ala.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO2	TiO2	Fe2O3	Al2O3	MnO	CaO	MgO	K2O	Na2O	P2O5	SO3	Ignition loss	Total	N	CO2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28902	A	0- 4	[a] 88.83	0.26	1.54	3.70	0.174	0.38	0.16	0.35	Tr.	0.02	0.09	5.37	100.87	0.120	------
			[b] 93.87	.27	1.63	3.90	.184	.40	.17	.37	Tr.	.02	.10	------	100.90		------
28903	B	4- 48	[a] 84.22	.72	4.42	7.50	.039	.17	.13	.32	Tr.	.07	.09	2.97	100.65	.030	------
			[b] 86.80	.74	4.55	7.73	.400	.18	.13	.33	Tr.	.07	.09	------	100.66		------
28904	C1	48- 78	[a] 75.83	.44	10.90	5.37	2.850	.30	.11	.23	Tr.	.08	.06	3.93	100.10	.020	------
			[b] 78.93	.46	11.34	5.59	2.960	.31	.11	.24	Tr.	.08	.06	------	100.10		------
28905	C2	78–114	[a] 84.50	.39	5.83	5.96	.030	.23	.08	.19	Tr.	.10	.11	2.82	100.24	.020	------
			[b] 86.99	.40	6.05	6.20	.030	.24	.08	.20	Tr.	.10	.11	------	100.28		------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28902	A	0- 4	1.0	7.6	9.9	51.8	8.7	13.1	7.8	99.9
28903	B	4- 48	1.5	8.1	6.4	42.6	10.5	20.7	10.1	99.9
28904	C1	48- 78	2.5	16.2	8.7	43.4	8.4	7.0	13.7	99.9
28905	C2	78–114	.6	8.6	8.2	53.4	5.9	3.5	19.6	99.8

[1] Collected by C. F. Marbut.
[2] Analyzed by R. S. Holmes, S. Mattson, G. Edgington, and I. A. Denison.
[3] Analyzed by A. A. White.

The several ratios and the relative molecular equivalent composition of the three horizons are shown in Table 81.

TABLE 81.—*Greenville sandy loam, Evergreen, Ala.*

Sample No.	Horizon	Depth in inches	Ratios sa	sf	ba	Molecular equivalent composition SiO2	Fe2O3	Al2O3
28902	A	0- 4	41	152.7	0.290	1.56	0.010	0.038
28903	B	4-48	19	50.5	.088	1.44	.028	.075
28904	C1	48+	24	18.5	.130	1.31	.071	.054

If the high content of iron oxide in horizon C_1 be a feature inherited from a former Norfolklike profile, as suggested in a preceding paragraph, it has no significance in the existing profile. The sa ratios show no significant difference in the content of alumina in B and C. The maximum percentage of iron oxide is not in horizon B but in C, or clearly in a deeper horizon than that in which the maximum percentage of alumina is found. The maximum percentage of silt and clay is present between depths of 4 and 48 inches. This constitutes the B horizon, and the maximum iron oxide accumulation is found in horizon C. Assuming that the horizon extending from 4 to 48 inches is a true podzolic B horizon, it is apparent that, according to the existing knowledge of normal soil development, the iron oxide accumulation in C is not a normal product of soil development. On the basis of the suggestion offered by the Norfolk and Tifton soils, the simplest explanation of its origin is that it was developed at ground water level before the existing cycle of topographic development had, by valley cutting, reduced the ground water surface to its present level, well below the deepest part of this sample. This excess of iron oxide is an inheritance from a time when conditions were similar to those now prevailing in the region of typical Norfolk soils in the Carolinas.

The chemical and mechanical composition of material from a profile of Greenville sandy loam from Quitman County, Ga., are shown in Table 82.

TABLE 82.—*Composition of Greenville sandy loam, Georgetown, Quitman County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO2	TiO2	Fe2O3	Al2O3	MnO	CaO	MgO	K2O	Na2O	P2O5	SO3	Ignition loss	Total	N	CO2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
258506	A1	0- 2	[a] 78.70	0.84	3.48	7.23	0.09	0.40	0.14	0.18	0.74	0.17	0.24	8.57	100.78	0.150	------
			[b] 86.04	.92	3.81	7.91	.10	.44	.15	.20	.81	.19	.26	------	100.83		------
258507	A2	2- 9	[a] 84.00	.71	3.30	6.10	.05	Tr.	.20	.09	.56	.10	.10	4.68	99.89	.050	------
			[b] 88.11	.74	3.46	6.40	.05	Tr.	.21	.09	.59	.11	.11	------	99.85		------
258508	B1	9-40	[a] 56.63	.90	10.70	20.87	.02	Tr.	.14	.19	.57	.17	.16	9.77	100.12	.020	------
			[b] 62.77	1.00	11.86	23.11	.02	Tr.	.16	.21	.63	.19	.18	------	100.13		------
258509	B2	40-52	[a] 62.70	.81	12.36	15.51	.03	Tr.	.08	.25	.54	.24	.15	7.72	100.39	.010	------
			[b] 67.93	.88	13.38	16.80	.03	Tr.	.09	.27	.58	.26	.16	------	100.38		------
258510	C1	52-55	[a] 61.00	.50	20.36	9.07	1.02	.22	.22	.07	.53	.28	.15	7.37	100.79	.014	------
			[b] 65.85	.54	21.96	9.79	1.10	.24	.24	.08	.57	.30	.16	------	100.83		------
258511	C2	55-70	[a] 59.77	.90	16.84	12.73	.02	.20	.07	.20	.52	.18	.13	7.90	99.46	.003	------
			[b] 64.88	.98	18.28	13.82	.02	.22	.08	.22	.56	.20	.14	------	99.40		------
258512	C3	70-96	[a] 65.11	1.01	8.97	17.29	.01	.06	.18	.44	.12	.06	.17	6.60	100.02	.003	------
			[b] 69.73	1.08	9.61	18.51	.01	.06	.19	.47	.13	.06	.18	------	100.03		------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
258506	A1	0- 2	1.2	9.8	10.6	24.4	10.0	22.3	21.7	100.0
258507	A2	2- 9	2.3	10.9	16.6	28.6	11.1	11.4	19.5	100.4
258508	B1	9-40	1.3	6.8	8.1	12.2	4.6	6.1	61.0	100.1
258509	B2	40-52	5.0	12.5	8.1	12.6	6.5	5.0	50.3	100.0
258510	C1	52-55	9.0	19.5	15.8	17.0	5.0	6.3	27.5	100.1
258511	C2	55-70	1.1	6.4	6.8	14.1	11.1	12.0	48.5	100.0
258512	C3	70-96	1.3	7.3	6.1	14.7	11.4	13.8	45.5	100.1

[1] Collected by R E. Devereux.
[2] Analyzed by G. J. Hough.
[3] Analyzed by L. T. Alexander.

The complete chemical composition table shows differences in composition in the several layers, seemingly due to geological conditions. The increase in percentage of alumina in what is considered C_2, continuing in C_3, well above that in C_1 is probably due to the presence at this depth of a geological stratum with more clay than in C_1. The rather high percentage of alumina in A_1 is characteristic of the Greenville soils in comparison with the Orangeburg, Norfolk, and Tifton soils. This type of Greenville is sandy loam but it contains twice as much alumina, presumably in clay, as the surface soils of the sandy loams of the series mentioned. The percentage is much higher than that in the surface layer of Orangeburg sandy loam and is twice as high as in Greenville sandy loam from Evergreen, Ala. Greenville sandy loam is almost as heavy as a loam.

The horizons of the profile are well expressed in both the chemical and mechanical composition. The B horizon contains 61 per cent of clay. The percentage of iron oxide attains a maximum of 22 per cent in horizon C_1, suggesting the possibility of ground water influence at an earlier period. The occurrence of the maxima of iron oxide and alumina in entirely different horizons of the profile point without doubt to the influence of some other factor than the usual factors producing the podzolic profile. The latter would place the maxima of both constituents in the same (B) horizon.

The several ratios and molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 83.

TABLE 83.—*Greenville sandy loam, Quitman County, Ga.*

Sample No.	Horizon	Depth in inches	Ratios sa	sf	ba	Molecular equivalent composition SiO2	Fe2O3	Al2O3
258507	A2	2- 9	23.40	67.48	0.167	1.46	0.0216	0.0628
258508	B1	9-40	4.62	14.02	.054	1.04	.0742	.2260
258510	C1	52-55	11.40	7.90	.149	1.09	.1370	.0960

The relative number of silica molecules in B_1 and C_1 differs very slightly, that in B_1 being about 3 per cent smaller than in C_1. The number in A_2 is much larger, being 36 per cent larger than in C_1. The relative number of alumina molecules in B_1 is more than twice the number in C_1, but in A_2 is a third less than in C_1. The sa ratios emphasize the difference between the A_2 and B_1 horizons and show a slight difference between B_1 and C_1. The percentages of alkalies and alkaline earths are all very low, lime in the solum, except that in the dark layer, A_1, being almost lacking.

The chemical and mechanical composition of material from a Greenville profile in Butler County, Ala., are shown in Table 84. The C horizon is not included. The general physical character of the soil in place shows it to be an excellent representation of the A and B horizons of the Greenville. The composition shows the usual features, a podzolic profile, the percentages of iron oxide and alumina being high in B and low in A. The alkalies and alkaline earths are all low, the soil being typical in this respect of the sandy Red and Yellow soils.

TABLE 84.—*Composition of Greenville fine sandy loam, Greenville, Butler County, Ala.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO2	TiO2	Fe2O3	Al2O3	MnO	CaO	MgO	K2O	Na2O	P2O5	SO3	Ignition loss	Total	N	CO2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28906	A	0–10	[a] 89.36	1.11	1.61	2.95	0.76	0.22	0.34	0.36	0.58	0.04	0.04	3.02	100.39	0.006	------
			[b] 92.12	1.14	1.66	3.04	.78	.23	.35	.37	.60	.04	.04	------	100.37		------
28907	B1	10–36	[a] 76.47	.97	4.33	13.00	.016	.23	.45	.23	.01	.37	.10	4.86	101.04	.030	------
			[b] 80.38	1.02	4.55	13.67	.017	.24	.47	.24	.01	.39	.11	------	101.02		------
28908	B2	36–60	[a] 66.26	1.28	8.76	16.20	.004	.26	.25	.36	.22	.07	.20	6.20	100.06	.020	------
			[b] 70.66	1.36	9.34	17.27	.004	.28	.27	.38	.23	.07	.21	------	100.07		------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28906	A	0–10	0.6	5.1	6.4	44.6	17.0	18.0	8.2	99.9
28907	B1	10–36	.2	2.5	4.5	28.2	13.7	13.0	37.8	99.9
28908	B2	36–60	.8	3.2	2.6	16.0	28.6	9.1	39.7	100.0

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough.
[3] Analyzed by A. A. White.

A Greenville sandy loam from Tallahassee, Fla., the composition of which is shown in Table 85, contains a lower percentage of both alumina and iron oxide than the samples previously mentioned. This, however, is a Red soil, not Yellow. It is underlain by limestone at a depth of many feet.

TABLE 85.—*Composition of Greenville sandy loam, Tallahassee, Fla.*[1]

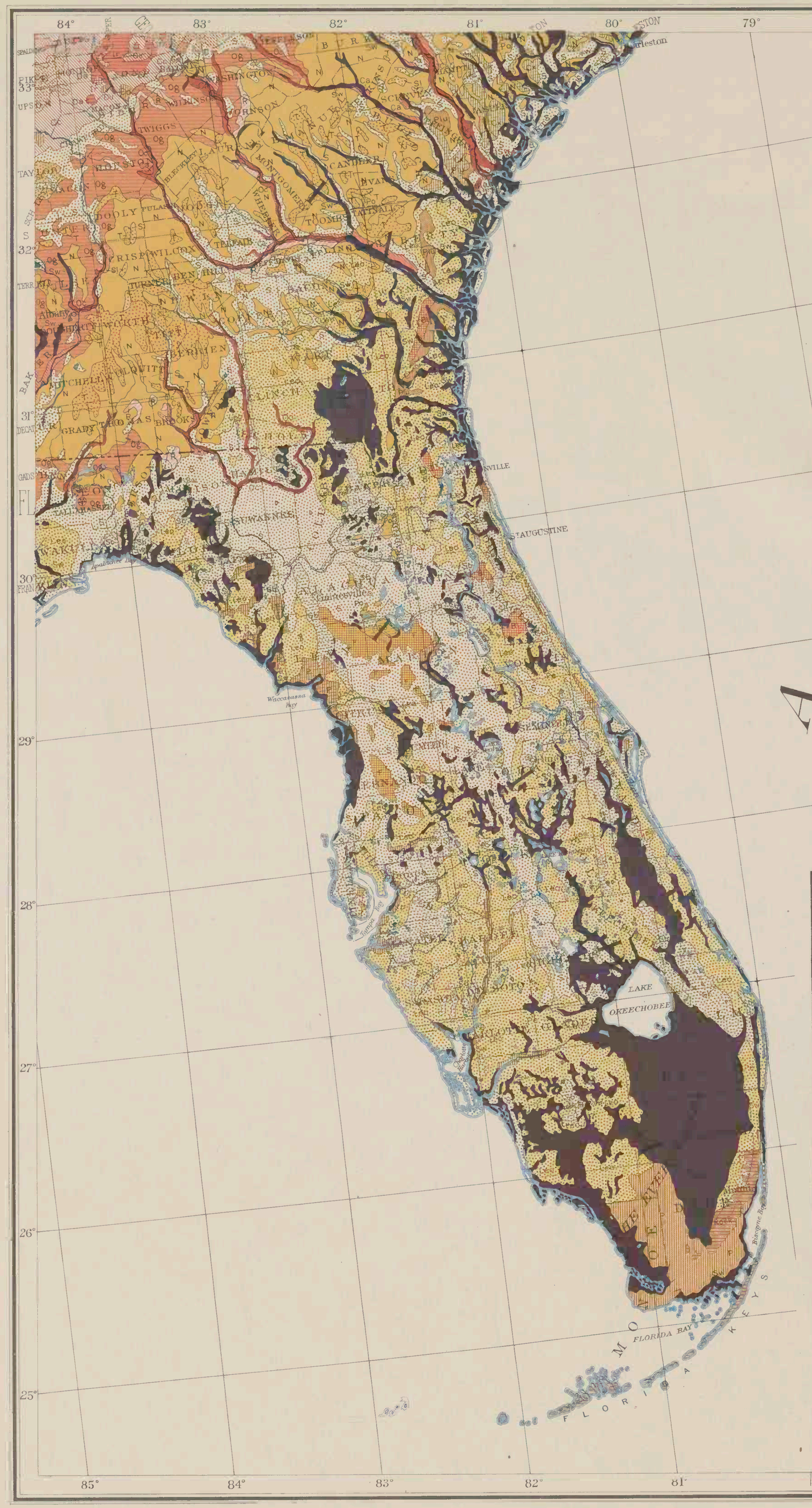
Sample No.	Horizon	Depth	Chemical [2] SiO2	TiO2	Fe2O3	Al2O3	MnO	CaO	MgO	K2O	Na2O	P2O5	SO3	Ignition loss	Total	N	CO2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28559	A1	0- 8	[a] 86.41	0.50	1.66	6.04	0.065	0.07	0.25	0.12	0.04	0.64	0.08	4.47	100.35	0.080	------
			[b] 90.44	.52	1.74	6.33	.068	.07	.26	.13	.04	.67	.08	------	100.35		------
28560	A2	8–40	[a] 89.36	.32	1.93	4.86	.030	.54	.40	.20	Tr.	.60	.03	2.45	100.72	.020	------
			[b] 91.60	.33	1.98	4.98	.030	.55	.41	.20	Tr.	.62	.03	------	100.73		------
28561	B	40–60	[a] 82.50	.32	2.56	6.76	.012	.60	.22	.15	Tr.	2.53	.04	3.95	99.64	.020	------
			[b] 85.90	.33	2.66	7.04	.012	.62	.23	.16	Tr.	2.63	.04	------	99.62		------
28562	C	60–90	[a] 80.58	.32	2.26	7.84	.024	.56	.26	.23	Tr.	3.56	.03	4.40	100.06	.020	------
			[b] 84.31	.33	2.36	8.20	.025	.59	.27	.24	Tr.	3.72	.03	------	100.06		------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28559	A1	0- 8	1.2	16.0	19.0	40.1	4.8	6.2	12.6	99.9
28560	A2	8–40	2.4	23.3	18.0	36.8	3.4	4.2	12.0	100.1
28561	B	40–60	1.3	18.8	20.2	34.0	4.6	2.7	18.4	100.0
28562	C	60–90	3.0	11.6	9.7	42.4	12.2	6.0	15.0	99.9

[1] Collected by J. O. Veatch.
[2] Analyzed by G. J. Hough, G. Edgington, S. Mattson, and I. A. Denison.
[3] Analyzed by A. A. White.

COMPOSITION OF GRENADA AND MEMPHIS SOILS

Grenada and Memphis soils occupy a belt of upland stretching along both sides of the Mississippi River Valley from St. Louis to within a few miles of New Orleans. This belt is most continuous and widest on the east side of the valley, ranging up to about 50 miles in width. The soils have developed from silty materials identified



SOIL MAP
OF THE
UNITED STATES

BY

CURTIS F. MARBUT

AND ASSOCIATES IN THE SOIL SURVEY
U. S. DEPARTMENT OF AGRICULTURE

F. J. MARSCHNER, CARTOGRAPHER AND ASSOCIATE IN COMPILATION

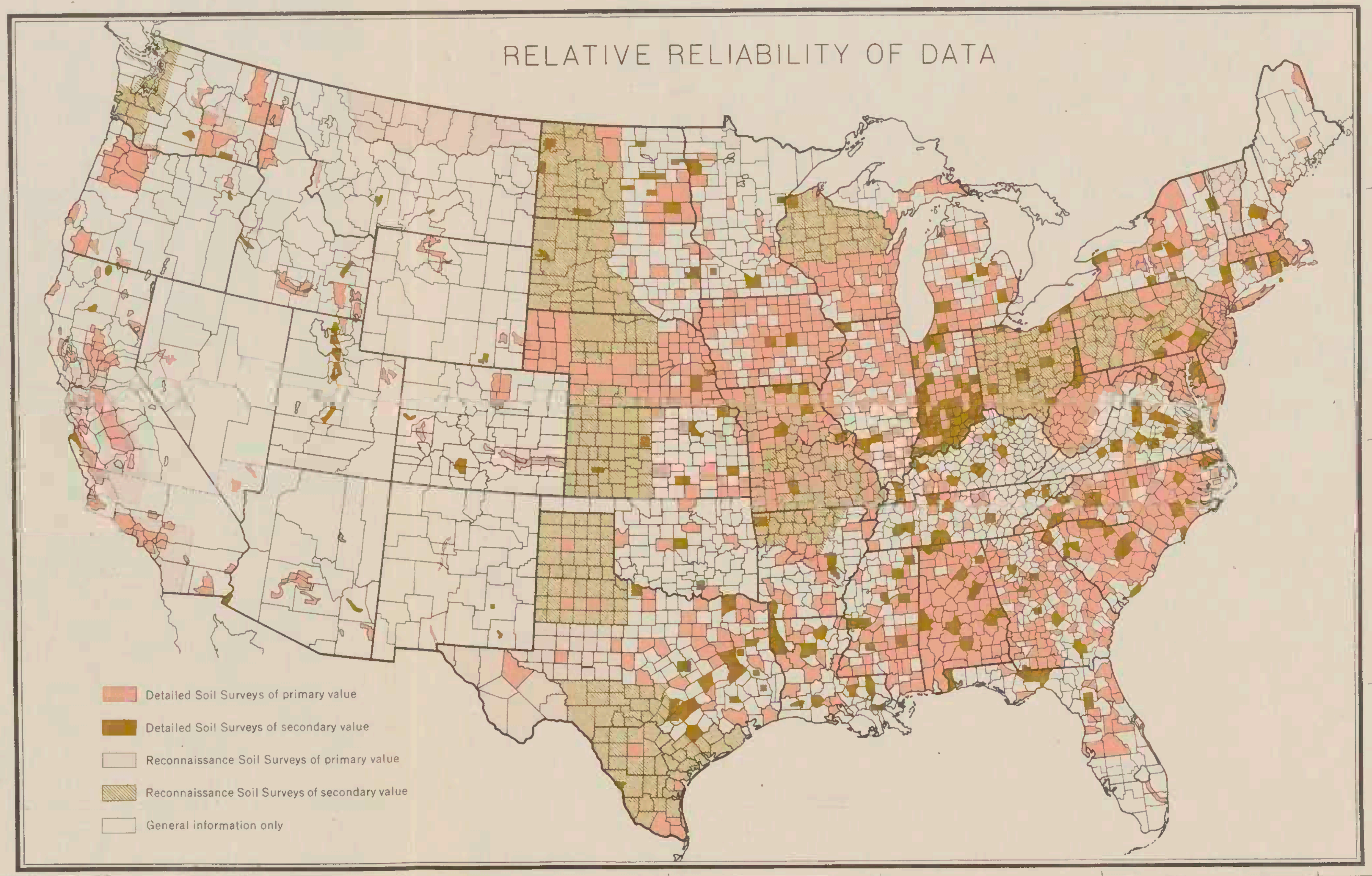
Scale $\frac{1}{2,500,000}$

APPROXIMATELY 40 MILES TO 1 INCH

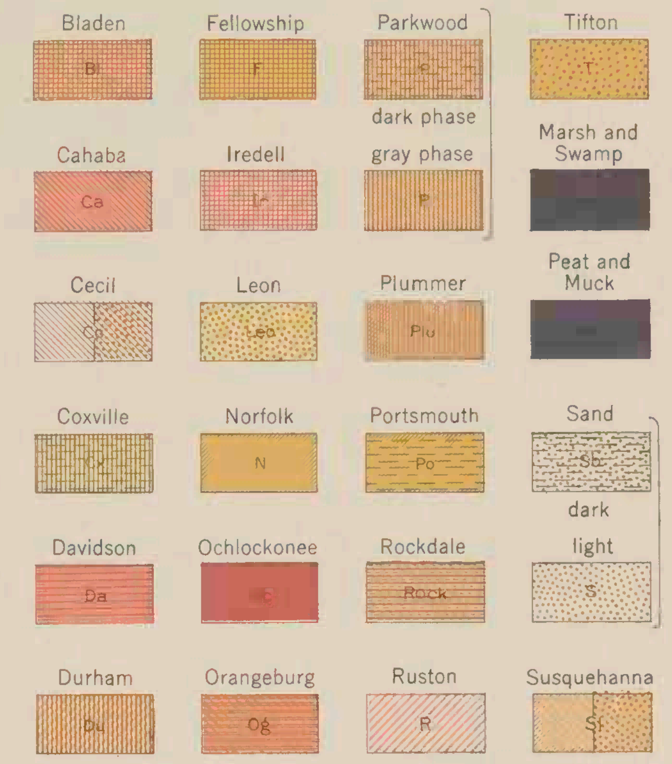
1931

BASE MAP BY U. S. GEOLOGICAL SURVEY (1919)

RELATIVE RELIABILITY OF DATA



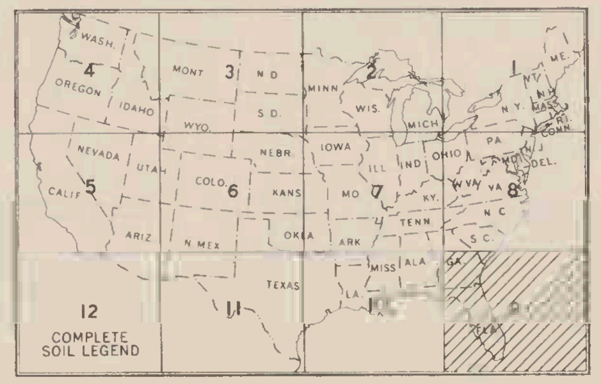
LEGEND FOR THIS SECTION



Virgin longleaf pine on Norfolk sandy loam, Lowndes County, Ga.

Orange grove on Norfolk fine sand, near Lakeland, Polk County, Fla.

ARRANGEMENT OF SECTIONS



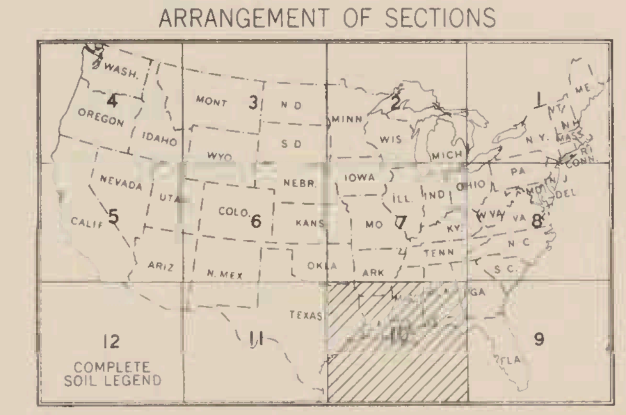
LEGEND FOR THIS SECTION

Caddo	Grenada	Miller	Sharkey
Cahaba	Hanceville	Myatt	Susquehanna
Cecil	Harris	Norfolk	Talladega
Clarksville	Hartsells	Ochlockonee	Tifton
Crawford	Houston	Oktibbeha	Trinity
Crowley	Katy	Olivier	Waverly
Davidson	Lake Charles	Orangeburg	Marsh and Swamp
Decatur	Leon	Plummer	Peat and Muck
Durant	Louisa	Portland	Rough and Stony land
Durham	Lufkin	Ruston	Sand: dark
Frio	Memphis	Sarpy	Sand: light

Hardwood forest on Memphis silt loam near Yazoo City, Yazoo County, Miss.

Cotton in Lauderdale County, Miss., grown on red land (terrace) soils of the Ruston group

ARRANGEMENT OF SECTIONS



Lith. A. Hoen & Co., Inc.

generally by geologists as loess. The deposit overlies the sandy materials of the coastal plain south of Cairo. It is thickest, ranging in thickness up to 50 feet or more, along the river bluffs, and it thins eastward. It is calcareous below the level of leaching, the calcareous material lying several feet below the surface, but it is rarely found except along the bluff side of the belt where erosion tends to keep pace with leaching. The Memphis soils are those lying along the bluffs where calcareous material lies, in most places, at a depth of less than 10 feet. The Grenada soils lie on the smooth uplands east of the bluffs, in situations where the material has not been subjected to erosion, and soil-developing processes have been operating for a long time.

A sample of Grenada silt loam from Rankin County, Miss., the composition of which is shown in Table 86, is a well-leached soil with a normally developed podzolic profile. The alumina, iron oxide, and lime are high in the thin half-inch layer of leaf mold, the A_0 horizon. The B_1 horizon, from 7 to 20 inches, is well expressed in its high content of iron oxide and alumina.

TABLE 86.—*Composition of Grenada silt loam, Rankin County, Miss.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
425001	A_0	0–½	[a]75.04	0.71	2.70	7.26	0.099	0.61	0.33	1.21	0.68	0.06	0.07	10.92	99.69	0.190	------
			[b]84.24	.81	3.03	8.15	.111	.68	.37	1.36	.76	.07	.08	------	99.66	------	------
425002	A_1	½–7	[a]85.39	.82	1.87	6.45	.015	.13	.16	1.37	.80	.01	.02	2.53	99.57	.018	------
			[b]87.61	.84	1.92	6.62	.015	.13	.16	1.41	.82	.01	.02	------	99.56	------	------
425003	B_1	7–20	[a]74.00	.85	4.97	12.24	.021	.16	.50	1.53	.85	.05	.02	4.76	99.95	.039	------
			[b]77.69	.89	5.22	12.85	.022	.17	.52	1.61	.89	.05	.02	------	99.93	------	------
425004	B_2	20–35	[a]80.80	.79	3.34	9.10	.031	.27	.52	1.27	.87	.02	.03	2.73	99.77	.013	------
			[b]83.07	.81	3.43	9.35	.032	.28	.53	1.31	.90	.02	.03	------	99.76	------	------
425005	C	35–60	[a]87.19	.86	2.08	6.28	.014	.10	.27	.63	.40	.01	.05	2.11	99.99	.005	------
			[b]89.05	.88	2.12	6.42	.014	.10	.28	.64	.41	.01	.05	------	99.97	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
425001	A_0	0–½	0.5	1.8	2.7	5.9	2.1	68.4	18.5	99.9
425002	A_1	½–7	.1	.8	2.2	5.3	2.6	76.1	12.8	99.9
425003	B_1	7–20	.0	.3	.9	2.5	1.2	61.4	33.7	100.0
425004	B_2	20–35	.1	.9	2.2	5.5	2.2	65.9	23.1	99.9
425005	C	35–60	.2	1.0	3.1	8.4	2.9	64.4	20.0	100.0

[1] Collected by R. Wildermuth.
[2] Analyzed by G. Edgington.
[3] Analyzed by L. T. Alexander.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 87.

TABLE 87.—*Grenada silt loam, Rankin County, Miss.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
425002	A_1	½–7	22.50	120.9	0.471	1.46	0.012	0.0649
425003	B_1	7–20	10.30	39.4	.274	1.28	.0327	.1260
425005	C	35–60	23.60	111.3	.241	1.47	.0100	.0630

Accumulation of both iron oxide and alumina has taken place. Since both sa and the molecular ratios show not only no decrease of alumina in A_1 over that in C, but a slight increase, it is not clear what explanation can be given unless there be an error in the analysis. The latter possibility is suggested by the results of an analysis of another Grenada profile from Grenada, Miss., shown in Table 88. In this profile the molecular ratios of alumina in A, B, and C are 0.091, 0.111, and 0.097, respectively, the normal podzolic relationship. One respect in which both the profiles of the Grenada soils differ from the other upland soils of the Southern States considered up to this point is the high percentages of potash and soda and, to less extent, of lime.

This is a reflection both of the character of the parent material, which is calcareous, and also of its more recent accumulation. Time has not yet elapsed for thorough leaching. The soils from this material have not yet reached the same stage of development as the sandy soils of the coastal plain with which they are geographically associated.

The chemical composition of material from a well-developed profile of Grenada silt loam from Grenada County, Miss., is shown in Table 88.

TABLE 88.—*Chemical composition of Grenada silt loam, Grenada, Grenada County, Miss.*[1] [2]

Sample No.	Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28006	A	0–6	[a]78.57	1.06	3.93	8.92	------	0.37	0.02	2.10	1.03	0.04	0.05	4.36	100.45	------	------
			[b]82.14	1.11	4.11	9.32	------	.39	.02	2.19	1.08	.04	.05	------	100.45	------	------
28007	B_1	7–30	[a]76.03	1.03	4.84	10.85	------	.68	.02	1.99	.94	.02	.01	4.30	100.71	------	------
			[b]79.42	1.08	5.06	11.33	------	.71	.02	2.08	.98	.02	.01	------	100.71	------	------
28008	B_2	32–48	[a]77.25	1.09	4.66	10.30	------	.42	.02	2.24	1.28	.06	.02	3.28	100.62	------	------
			[b]79.86	1.13	4.82	10.65	------	.43	.02	2.32	1.32	.06	.02	------	100.63	------	------
28009	C	50+	[a]76.78	.97	4.65	9.72	------	1.20	1.18	2.33	1.49	.03	.02	2.70	101.07	------	------
			[b]78.89	1.00	4.78	9.99	------	1.23	1.21	2.39	1.53	.03	.02	------	101.07	------	------

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Sept. 26, 1916.

The soil in the field has a well-defined color profile with a yellowish silty A horizon and a reddish B. The chemical analysis shows slight apparent accumulation of iron oxide and alumina in B over the amounts in C. The percentage of K_2O is very high for a mature soil in this latitude, and that of CaO in the C horizon is high. The silty texture of the material, its probable source in Mississippi River deposits, and its comparatively recent accumulation are all involved in the explanation of these high percentages.

The soil is not a typical Red or Yellow soil. It is developing into such a soil, but its features are not yet pronounced.

[19] Combined on the soil map, Plate 5, section 10, with Orangeburg.

The several ratios and molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 89. The quantities, both absolute and relative, are more like those of a Gray-Brown Podzolic soil than of a Yellow soil.

TABLE 89.—*Grenada silt loam, Grenada, Miss.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
28006	A	0–6	14.98	52.95	0.522	1.36	0.025	0.091
28007	B_1	7–30	11.91	41.60	.455	1.31	.031	.111
28009	C	50+	13.42	43.73	.738	1.31	.03	.097

COMPOSITION OF DECATUR, HANCEVILLE, AND NACOGDOCHES SOILS

The Decatur soils are Red soils and have been developed from material accumulated by the decay of limestones. As is universally the case, these soils have light-colored brown, yellow, or still lighter colored A horizons where the profile has not been mutilated by erosion. In those cases where the red color extends to the surface, the A horizon has been removed.

The composition of a profile of Decatur silt loam, from Childersburg, Ala., is shown in Table 90. The percentages of alumina and iron oxide both increase continuously downward. This is possibly owing to the character of the local parent limestone, but the information available does not warrant a definite conclusion. The A horizon is brown, and a well-defined red color appears at a depth of 10 inches.

TABLE 90.—*Composition of Decatur silt loam, Childersburg, Ala.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
30248	A_1	0–3	[a]85.53	1.00	2.06	5.31	0.229	0.12	0.15	0.45	0.07	Tr.	0.11	5.00	100.03	0.092	------
			[b]90.05	1.05	2.17	5.59	.241	.13	.16	.47	.07	Tr.	.12	------	100.05	------	------
30249	A_2	3–6	[a]84.80	.96	2.31	6.19	.282	.12	.23	.52	.05	Tr.	.11	4.55	100.12	.071	------
			[b]88.82	1.01	2.42	6.49	.295	.13	.24	.54	.05	Tr.	.12	------	100.12	------	------
30250	A_3	7–10	[a]83.16	1.20	3.39	7.37	.150	.24	.48	.33	.48	0.07	.09	3.91	100.87	.050	------
			[b]86.54	1.25	3.53	7.67	.160	.25	.50	.34	.50	.07	.09	------	100.85	------	------
30251	A_4	11–18	[a]80.77	1.20	4.02	9.33	.030	.20	.53	.51	.48	.05	.08	3.40	100.60	.020	------
			[b]83.61	1.24	4.16	9.66	.030	.21	.55	.53	.50	.05	.08	------	100.63	------	------
30252	B_1	19–40	[a]66.93	1.20	7.70	16.97	.026	.14	.63	.81	.53	.10	.10	5.84	100.97	.020	------
			[b]71.06	1.27	8.17	18.02	.028	.15	.67	.86	.56	.11	.11	------	101.01	------	------
30253	C	41–70	[a]51.32	1.20	9.18	25.38	.015	.14	.96	1.74	.57	.14	.12	9.53	100.30	.020	------
			[b]56.71	1.33	10.03	28.09	.017	.15	1.06	1.92	.63	.15	.13	------	100.21	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
30248	A_1	0–3	3.4	5.4	3.0	11.2	11.0	51.8	14.3	100.1
30249, 30250	A_2	3–10	2.4	5.0	2.9	9.8	9.8	51.7	18.4	100.0
30251	A_4	11–18	2.0	3.6	1.8	6.4	8.6	48.6	29.1	100.1
30252	B_1	19–40	.8	2.4	1.2	4.4	6.0	36.0	49.2	100.0
30253	C	41–70	.4	1.0	.6	2.6	4.0	25.3	66.1	100.0

[1] Collected by Mark Baldwin.
[2] Analyzed by G. Edgington and G. J. Hough.
[3] Analyzed by A. A. White.

The Hanceville silt loam profile from Montevallo, Ala., whose composition is shown in Table 91, is the only Red soil developed from noncalcareous shale material which has been analyzed. The C horizon was not included. The analysis shows, by its low iron oxide and alumina and high silica in the upper 12 inches and the reverse condition below that, the familiar features of the podzolic profile. The material to a depth of 12 inches is brown, below that, red.

TABLE 91.—*Composition of Hanceville silt loam, Montevallo, Ala.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34733	A_1	0–3	[a]84.03	0.97	2.04	6.83	0.02	0.04	0.19	0.71	0.04	0.11	0.04	4.98	100.00	0.080	------
			[b]88.41	1.02	2.16	7.19	.02	.04	.20	.75	.04	.12	.05	------	100.00	------	------
34734	A_2	3–12	[a]82.45	.94	4.31	7.48	.01	.06	.19	.63	.07	.09	.08	3.69	100.00	.060	------
			[b]85.59	.98	4.48	7.77	.01	.06	.20	.65	.07	.09	.08	------	99.98	------	------
34735	B	12–36	[a]61.02	.99	8.88	19.64	.01	.13	.50	1.06	.06	.11	.05	7.55	100.00	.030	------
			[b]66.01	1.07	9.60	21.24	.01	.14	.54	1.15	.06	.12	.05	------	99.99	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34733	A_1	0–3	0.2	1.7	9.6	29.4	13.2	30.5	15.5	100.1
34734	A_2	3–12	0	1.4	9.0	27.8	12.3	29.8	19.7	100.0
34735	B	12–36	0	.8	8.4	20.3	7.9	21.7	40.9	100.1

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Dec. 8, 1917.
[3] Analyzed by L. T. Alexander.

The Nacogdoches[19] soils occupy relatively important areas in the coastal plain in Louisiana and eastern Texas. They have developed from unconsolidated sandy Tertiary deposits containing glauconite similar in character to that from which the Collington soils of New Jersey and Maryland have developed. In Texas and Louisiana decomposition has been much more thorough and has reached greater depth from the surface.

Nacogdoches fine sandy loam is the most intensely red soil identified within the boundaries of the United States up to the present time. The chemical and mechanical composition of material from a profile of Nacogdoches soil in Nacogdoches County, Tex., are shown in Table 92.

TABLE 92.—*Composition of Nacogdoches fine sandy loam, Nacogdoches County, Tex.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO$_2$	TiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$	MnO	CaO	MgO	K$_2$O	Na$_2$O	P$_2$O$_5$	SO$_3$	Ignition loss	Total	N	CO$_2$ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
447094	A	0–12	[a]85.20	0.59	8.18	3.34	0.072	0.11	0.09	0.29	0.30	0.05	0.04	2.18	100.44	0.022	-
			[b]87.09	.60	8.36	3.42	.074	.11	.09	.30	.31	.05	.04	-	100.44	-	-
33410	B$_1$	8–40	[a]38.27	.84	23.22	24.24	.018	.04	.62	.70	.28	.16	.06	11.63	100.08	.043	-
			[b]43.31	.95	26.27	27.43	.024	.05	.70	.79	.32	.18	.07	-	100.15	-	-
33411	B$_2$	40–72	[a]22.99	.72	45.23	16.45	.094	Tr.	.98	.58	.32	.73	.09	12.07	100.25	.008	-
			[b]26.14	.82	51.42	18.70	.107	Tr.	1.11	.66	.36	.83	.10	-	100.23	-	-
447099-1	C	72–168	[a]52.23	.67	16.02	17.82	.077	1.47	2.26	1.81	.44	.07	.05	7.57	100.49	.014	-
			[b]56.52	.72	17.33	19.28	.088	1.59	2.44	1.96	.48	.08	.05	-	100.58	-	-

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
447094	A	0–12	1.2	2.4	1.8	39.6	33.2	16.3	5.3	99.8
33410	B$_1$	8–40	1.3	2.0	1.8	5.0	4.2	7.6	78.2	100.1
447099-1	C	72–168	.1	1.3	1.1	20.0	11.0	21.4	43.6	98.7

[1] Collected by B. H. Hendrickson.
[2] Analyzed by G. Edgington.
[3] Analyzed by J. B. Spencer and V. Jacquot.

The table shows the composition of a profile made up from Nacogdoches soil from three localities, all in Nacogdoches County, Tex.

The A horizon has been converted into a light sandy loam by the removal of clay and silt, part of which has been removed entirely from the spot and part carried into the B horizon. The region is in a mature stage of topographic development, and the surface has been reduced to a somewhat lower level than that of the plain on which the existing cycle started.

Percentages of both iron oxide and alumina are very high in horizon B, being highest in the upper part and decreasing downward. The maximum percentage of iron oxide lies below the horizon containing the maximum percentage of alumina. This relationship was found in the coastal-plain soils of Georgia and Alabama and was explained as a possible result of the action of ground water during an earlier period when the land surface was smoother and possibly stood at a lower level than now.

The stage of development of soils in the Nacogdoches region of Texas is further advanced than that in the typical Norfolk region of the Carolinas or the Tifton region of Georgia, but this fact seems to constitute no basis for concluding that the iron oxide accumulation in the Nacogdoches profile is not due to the same cause. In both regions this explanation of its existence is based on a certain analogy with the iron oxide zone in tropical soils and the zone of apparent accumulation at the top of horizon C in the Norfolk soils.

The several ratios and the molecular equivalent composition for SiO$_2$, Fe$_2$O$_3$, and Al$_2$O$_3$ are shown in Table 93. The sa ratios show clearly the accumulation of alumina in B, but in this case, where the accumulation has been so great, the complete analysis of the whole soil, Table 92, shows it clearly. Iron oxide accumulation is equally clear in horizon B. The high ba ratio in C is due to high CaO and K$_2$O, the latter being present in the glauconite of the parent material and the former in a small percentage of calcium carbonate.

TABLE 93.—*Nacogdoches fine sandy loam, Nacogdoches County, Tex.*

Sample No.	Horizon	Depth in inches	Ratios sa	sf	ba	Molecular equivalent composition SiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$
447094	A	0–12	43.3	27.6	0.303	14.47	0.052	0.0335
33410	B$_1$	8–40	2.7	4.3	.054	7.21	.164	.2690
447099	C	72–168	5.0	8.6	.301	9.40	.108	.1890

SOILS OF THE PIEDMONT PLATEAU

The Red soils of the piedmont plateau have developed from residual sand, silt, and clay, the product of the disintegration and decomposition of crystalline gneisses and schists, slates, and more or less metamorphosed igneous rocks. The range in character among the gneisses and schists is very great. In those containing quartz, as is the case with most of them, the texture profile of the soil, where mature and not mutilated by erosion, consists of an A horizon of sand or very sandy material, a B horizon of clay or sandy clay, and a C horizon of loose disintegrated partly decomposed rock material. The color profile consists of a gray or yellowish A horizon, a red or yellowish-red B horizon, and in most places a red or reddish upper C horizon.

The rocks are very old. The upland surface soil, where intact, is probably not older than Tertiary, and most of the land surface is much younger than the few small areas of what seems to be part of the original peneplain upland. The upland peneplain has been so thoroughly dissected that most of the existing land surface of the region is the product of geologically recent erosion. Some of the soils are probably old. It is possible that some of the soils developed during the closing stages of the cycle of erosion which produced the upland peneplain, but studies in the region have not yet made it possible to say that the soil in any given spot is such an old soil. The soils of an important part of the region, however, are younger than any such product of a former topographic cycle.

A number of profiles have been studied in the region and samples collected and analyzed. In a number of cases colloidal materials have been extracted and analyzed, but in few cases has a profile at any given spot been subjected to complete analysis (mechanical and chemical) and to the extraction and analysis of the colloidal material.

The prevailing mature red soils of the piedmont region, derived from schists and gneisses, especially the latter, are identified as members of the Cecil series. Material from four Cecil profiles from North Carolina have been subjected to complete analysis. One is a clay loam, two are fine sandy loams, and one a sandy loam. One clay loam and one fine sandy loam are from Rutherford County in the southwestern part of the State near the eastern foot of the Blue Ridge plateau.

The soils of the piedmont plateau differ from the soils of the coastal plain very strikingly in the low percentages of silica and high percentages of alumina in the former.

Field conditions indicate that the soils of the plateau have developed normally, without any influence from ground water.

Cecil fine sandy loam from Rutherfordton, N. C., has a rather well defined profile, the A horizon, which is somewhat sandy, being 5 inches thick, and the B$_1$ horizon extending from 5 to 36 inches. The complete analysis of this sample is shown in Table 94.

TABLE 94.—*Composition of Cecil fine sandy loam, Rutherfordton, N. C.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO$_2$	TiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$	MnO	CaO	MgO	K$_2$O	Na$_2$O	P$_2$O$_5$	SO$_3$	Ignition loss	Total	N	CO$_2$ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34996	A	0–5	[a]64.64	1.81	4.80	15.60	0.07	0.18	0.72	2.62	0.38	0.09	-	9.34	100.25	-	-
			[b]71.29	2.00	5.29	17.21	.08	.20	.80	2.90	.42	.10	-	-	100.96	-	-
			[c]34.49	1.01	11.25	36.81	.09	.22	.56	.35	.06	.26	.20	14.43	99.73	-	-
			[d]40.33	1.08	13.10	43.00	.12	.26	.65	.41	.07	.31	.24	-	99.57	-	-
34997	B$_1$	5–36	[a]46.00	1.54	11.06	27.26	.05	.18	.67	1.40	.64	.10	-	11.59	100.49	-	-
			[b]52.00	1.74	12.51	30.83	.06	.20	.76	1.58	.72	.11	-	-	100.51	-	-
			[c]32.02	1.02	14.70	36.98	.06	.25	.13	.18	.13	.12	.12	13.15	99.86	-	-
			[d]36.78	1.18	16.90	42.59	.07	.29	.15	.21	.15	.14	.14	-	99.71	-	-
34998	C$_1$	72–96	[a]47.04	1.80	9.92	24.80	.15	.64	2.28	3.14	.68	.68	-	8.68	99.81	-	-
			[b]51.51	1.97	10.86	27.16	.16	.70	2.50	3.43	.74	.74	-	-	99.77	-	-
			[c]28.84	1.09	11.00	40.05	.14	.23	.14	.18	.09	.79	.11	16.60	99.26	-	-
			[d]34.59	1.31	13.20	48.00	.17	.28	.17	.22	.11	.95	.13	-	99.13	-	-
34999	C$_2$	112+	[a]55.72	.95	4.48	22.12	.10	2.54	1.48	5.16	2.94	1.21	-	3.08	99.78	-	-
			[b]57.49	.98	4.62	22.83	.10	2.62	1.53	5.32	3.03	1.25	-	-	99.77	-	-

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34996	A	0–5	4.8	12.4	7.8	27.2	9.8	22.9	15.6	100.5
34997	B$_1$	5–36	2.8	4.6	2.8	11.7	5.5	21.4	51.2	100.0
34998	C$_1$	72–96	1.8	12.7	11.7	37.7	8.0	14.2	14.2	100.3
34999	C$_2$	112+	14.0	22.3	12.4	33.2	8.3	8.8	1.5	100.5

[1] Collected by W. E. Hearn.
[2] Analyzed by I. A. Denison.
[3] Analyzed by V. Jacquot and J. B. Spencer.

The chemical and mechanical composition are consistent in showing a highly eluviated podzolic profile, low alkaline earths in the A and B horizons, but moderate to high percentages of both alkalies and alkaline earths in C$_1$ and C$_2$. The percentage of potash in C$_2$ indicates the presence of undecomposed minerals, this being confirmed by an inspection of the samples. The percentage of alumina in horizon A is more than 17 but that of iron oxide is only 5, explaining the light color of this highly eluviated horizon, whereas a percentage of 12 in horizon B explains why, with good drainage and hot long summers, the B horizon is red. The content of silica in A is high, but in B it is nearly a third less.

The several ratios and the molecular equivalent composition in SiO$_2$, Fe$_2$O$_3$, Al$_2$O$_3$, and of the combined alkalies and alkaline earths are shown in Table 95.

TABLE 95.—*Cecil fine sandy loam, Rutherfordton, N. C.*

Sample No.	Horizon	Depth in inches	Ratios sa	sf	ba	Molecular equivalent composition SiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$	Alkalies and alkaline earths
34996	A	0–5	7.04	35.70	0.244	1.182	0.033	0.168	0.041
34997	B$_1$	5–36	2.87	11.00	.106	.862	.078	.302	.032
34998	C$_1$	72–96	4.28	33.20	.680	.953	.029	.222	.152

The sa ratios show that the amount of alumina relative to silica in B$_1$ is a third more than in C$_1$, whereas that in A is one and six-tenths times as much. In these soils, derived from crystalline rocks, the difference between the ratios in B$_1$ and C$_1$ can not be ascribed entirely to accumulation by illuviation, as was done in the coastal-plain soils where not due to original sediments. The C$_1$ horizon in the piedmont plateau soils, especially this profile of the Cecil, contains undecomposed feldspathic minerals. Part of the increase of alumina in B$_1$ over that in C$_1$ is due to the decomposition, and consequent loss, of silica from these minerals by the time their products have been incorporated in B$_1$. The concentration of iron oxide is still greater, that in B$_1$ being three times that in C$_1$, and that in A is a little more than that in C. In this case there can be no question about the sufficiency of the gain in B$_1$ to compensate for the loss in A. The question of the source of the iron oxide in B$_1$ has been frequently raised by American workers. It has usually been ascribed to eluviation or podzolic profile development entirely. On the other hand it may have been accumulated through the influence of ground water. Harrassowitz (*8*) places a gray zone in Lateritic soils below the iron crust and makes them mutually dependent. In this case the iron crust is formed from material taken from the lower lying gray layer within the ground-water zone and concentrated at its surface. Campbell (*3*) is even more emphatic in ascribing the concentration of iron to ground water, but he does not discuss an underlying gray zone.

In the case of the Cecil soils it is practically certain that ground water can not have been a factor, since it lies now and has lain throughout late Pleistocene and recent times many feet below either the surface soil or the B horizon. The B horizon also in the Cecil soils is not the equivalent, either in form or position in the profile, of the iron oxide crust in Lateritic soils but on the other hand occupies the same position in the soil profile and has the same physical character as the B horizon of the Gray-Brown Podzolic soils. The accumulation of the iron oxide as a product of ground-water influence can not be considered a possibility in view of all these conditions.

The C$_2$ horizon consists of gray disintegrated but not leached rock which has not suffered oxidation and presumably not much chemical decomposition. The ba ratios (Table 95) show that the loss of bases between C$_1$ and B$_1$ is very great, B$_1$ containing, relative to alumina, only a sixth as much as C$_1$. The higher ratio in A

expresses the lower percentage of alumina, but it is also influenced partly by the higher percentage of bases in the organic matter.

The color of the A horizon[20] is reddish brown and shows less gray than the highly sandy, highly eluviated A horizon of much of the Cecil sandy loam. The mechanical composition shows that the A horizon contains 15 per cent of clay, an unusually high percentage for the A horizon of Cecil sandy loam or Cecil fine sandy loam. Both this and the color strongly suggest that the A horizon is what del Villar (*18*) would call a subserial A, or one developing on a former B. The probability that this is the case is still further suggested by the higher content of iron oxide in A than in C_2. An explanation of its presence, since it is clearly an accumulation, in any other way than as a B horizon now being converted into an A, after the former A has been removed by erosion and considerable progress has been made in the transformation, is apparently difficult.

The molecular equivalent figures show the same concentration of alumina in B as is shown by the sa ratios. The amount in A is a little more than half that in B_1 and about 22 per cent more than in C_2.

Eluviation has concentrated both iron oxide and alumina in B_1, although A has an unusually large amount of both and the removal of alkalies has been very great.

The work of Holmes and Edgington in studying the colloid from Miami and Chester soils has already been referred to (pp. 33 and 36.) Their work includes the study of the colloid of Cecil soils[21] from 15 localities, from North Carolina to Alabama, some including studies of the entire profile.

Among the Cecil profiles studied by them is that near Rutherfordton, N. C., discussed in the foregoing paragraphs. The composition of the colloid from the A, B_1, and C_1 horizons is shown also in Table 94.

TABLE 96.—*Colloid of Cecil fine sandy loam, Rutherford County, N. C.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3
34996	A	0– 5	1.59	8.15	0.040	5.47	0.67	3.45
34997	B_1	5–36	1.46	5.8	.022	5.25	.91	3.58
34998	C_1	72–96	1.22	7.0	.024	4.75	.68	3.90
34999	C_2	112+						2.23

The percentage of sesquioxides in A is more than twice as large in the colloid as in the soil but the sum of the percentages of the alkalies and alkaline earths is much lower. The percentage of CaO is nearly the same in both, but the K_2O in the soil is about seven times that in the colloid. The percentage of silica is much lower in the colloid. The percentages of sesquioxides in the colloid are very nearly the same in all the soil horizons, that of iron oxide being a little higher in B_1, that of alumina in C_1. The percentage of Fe_2O_3 in B_1 is nearly 25 per cent higher than in C_1. The greater accumulation of iron oxide than of alumina in B seems to be in harmony with the suggestions obtained from a study of the coastal-plains soils, that the iron oxide accumulation in the Red and Yellow soils is generally greater than that of alumina. In the coastal-plain soils it was not everywhere present in the B horizon and because of this was tentatively explained as the product of ground water. In the Cecil soils it occurs in horizon B and when present is not a product of ground water.

The sa ratios for the three horizons (table 96) seem to be very significant. If the bases were present mainly in the form of absorbed bases on the colloid and if the soil minerals were so thoroughly decomposed that the whole soil, other than quartz, is colloid, the ratios for the same horizons in whole soil and colloid should be about the same. A mere inspection of samples of the whole soil shows that a very small proportion of undecomposed minerals remains, consisting mainly of mica flakes and quartz. It is apparent, therefore, on account of the large proportion of colloid in the whole soil, that the bases are present to an important extent in the mica flakes, and that a relatively small amount is present as absorbed bases.

The significance of the relationship of ba in the soil and in the colloid is well brought out by a comparison of the ba ratios in the whole soil of Miami silt loam Hancock County, Ind., (table 148, p. 70) and of the colloid from it with these ratios for the Cecil soil and colloid. This relationship is best shown by comparing ba ratios in soil and colloid for the B horizons in both soils. In the Miami silt loam, whole soil, ba in B is 0.387, and that for the colloid of the same soil and horizon is 0.172. That in the colloid is about half that in the whole soil. In Cecil fine sandy loam, ba in the B horizon for the whole soil is 0.106, and that in the colloid for the same soil and horizon is 0.022, only about a fifth that in the whole soil. The absorbing capacity of the colloid in the Miami is higher than that in the Cecil.

After the preceding paragraph was written the work of Holmes and Edgington (*10*) was published. The results show that the average base-exchange capacity of colloid from B horizon of 9 profiles of Miami soils is 38.7 milliequivalents per 100 grams; that of the B horizon of 17 samples of Cecil soils is 7.9 per 100 grams.

The high silica in the colloid of the A horizon may be due to the presence of quartz of colloidal size or to the presence of feldspathic or micaceous minerals, but the low base content makes the presence of the latter highly improbable.

Both the sa ratios and the molecular equivalent composition show low alumina in A and B as compared with C_1, but it is high in all horizons of the whole soil when compared with the molecular equivalent composition of C_2.

In this soil, especially in the B horizon where the percentage of undecomposed silicate mineral (mica) is very small and where the iron is practically all in the form of oxide, the silica is practically all in combination with the alumina except such small amount as may be present as quartz. The percentage of silica in the colloid of the B horizon, 37.34, multiplied by 0.847 gives 31.6. This is the percentage of alumina required by the silica if all the latter be combined with alumina in the molecular ratio of 1 alumina to 2 silica. Since the percentage of alumina present is 36.57 it is apparent that a considerable part of it must be present as free alumina. This is indicated also by the sa ratio which is below 2 in all horizons.

However much silica may be present in other forms than in combination with alumina at a 1 to 2 molecular ratio does not affect this conclusion. If any such silica were present the effect would be to increase the relative quantity of free alumina.

The percentage of quartz present in B as determined by microscopic analysis by Fry in the laboratories of the Bureau of Chemistry and Soils is 19. Deducting this from 52, the percentage in the whole soil, leaves 33. The percentage of silica in the colloid of B, as determined chemically by Holmes, being 31.67 is very close to that determined by Fry, giving a high degree of confidence in the microscopic method when handled skillfully.

The composition of a sample of Cecil clay loam from Green Hill, N. C., is shown in Table 97.

TABLE 97.—*Composition of Cecil clay loam, Green Hill, N. C.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Per ct.*	*P. ct.*	*P. ct.*
236504	A_1	0– 1	[a]58.96	1.41	5.10	16.28	0.076	0.05	0.37	2.24	0.67	0.10	0.08	15.04	100.38	0.169	
			[b]69.38	1.66	6.00	19.16	.089	.06	.44	2.64	.79	.12	.09		100.43		
236505	A_2	1– 6	[a]58.33	1.47	6.38	20.06	.056	Tr.	.58	2.20	.45	.10	.07	10.79	100.49	.081	
			[b]65.38	1.65	7.15	22.48	.063	Tr.	.65	2.46	.50	.11	.08		100.52		
236506	B_1	6–40	[a]49.95	1.43	9.31	26.54	.040	Tr.	.45	1.43	.40	.04	.07	10.63	100.29	.026	
			[b]55.88	1.60	10.42	29.69	.050	Tr.	.50	1.60	.45	.04	.08		100.31		
236507–8	B_2	40–84	[a]44.68	2.11	11.36	27.68	.095	Tr.	1.30	1.88	.32	.18	.05	10.59	100.25	.006	
			[b]49.97	2.36	12.70	30.94	.106	Tr.	1.45	2.10	.36	.20	.06		100.25		
236509	C	84+	[a]51.39	1.23	5.56	24.72	.125	1.03	1.43	5.84	1.90	.64	.03	5.63	99.52	.000	
			[b]54.46	1.30	5.89	26.19	.130	1.09	1.56	6.19	2.01	.68	.03		99.53		

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
236504	A_1	0– 1	3.0	10.1	4.6	21.6	8.4	25.9	26.3	99.9
236505	A_2	1– 6	2.8	7.0	4.0	20.6	9.6	26.6	29.5	100.1
236506	B_1	6–40	2.4	5.4	2.8	12.6	8.0	24.7	44.1	100.0
236507–8	B_2	40–84	1.0	6.0	6.6	23.5	9.9	21.9	31.3	100.1
236509	C	84+	5.0	18.6	11.0	34.6	8.0	14.1	8.7	100.0

[1] Collected by R. C. Jurney.
[2] Analyzed by G. Edgington.
[3] Analyzed by A. A. White.

The soil contains a high percentage of alumina in the A_2 horizon, the first two figure lines representing a very thin A_1. It has already been explained that Cecil clay loam is usually a subserial soil where it has any A horizon at all. Otherwise it is merely a mutilated sandy loam or fine sandy loam. The fine sandy loam from Rutherford County, N. C., was described as a probable subserial soil, but it is one in which the development of a new A on the old B has attained a more advanced stage than that attained in the clay loam from Green Hill, N. C.

Notwithstanding the fact that the texture of this soil is clay loam, it is well eluviated. The A horizon still contains a relatively high percentage of iron oxide, enough to give it a well-defined reddish shade. The apparent percentage in A_1 is, however, only about half as much as in B_2. Of alumina also the B_2 horizon contains 50 per cent more than in A_1. Alkaline earths have been almost entirely leached out of the solum but the percentage of potash is still relatively high, but lower in B_1 than in A. In C it is high. The percentage of combined water is high, indicating a high degree of decomposition of the soil minerals.

The several ratios and the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3, and of the combined aklalies and alkaline earths are shown in Table 98.

TABLE 98.—*Cecil clay loam, Green Hill, N. C.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
236505	A_2	1– 6	4.94	24.23	0.155	1.08	0.0440	0.220	0.034
236507 236508	B_2	40–84	2.74	10.42	.092	.83	.0800	.302	.028
236509	C	84+	3.53	24.50	.458	.90	.0369	.256	.117

The sa ratio for C is nearly 35 per cent greater than for B_2, showing an important accumulation of alumina in B_2. That for A_2, however, shows lower alumina than in B_2 or C. The amount of iron oxide in B_2 is more than twice that in C on the basis of an assumption of no removal of silica from B_2. Some removal has probably taken place as a result of decomposition of minerals. This is comparatively small, so that the accumulation of iron oxide has been heavy. The amount of alumina in B_2 over that in A_2, on the same assumption, is much less than twice that in C. Such loss of silica through mineral decomposition as has taken place has affected alumina in the same way as iron oxide. The accumulation of iron oxide in B_2, therefore, has been much greater, compared with C, than of alumina. This is brought out more clearly and given numerical expression by comparing the iron oxide-alumina ratios of the B_2 and C horizons. The ratio in B_2 is 10.4, and in C it is 7. The ba ratios bring out the heavy loss of alkalies and alkaline earths, the apparent loss for B_2, however, being greater than for A_2.

A Cecil fine sandy loam from Brooks Cross Roads in Yadkin County, N. C., shows a wider range of differences between A and B than the two Cecil soils already described, being a sandy loam in further stage of development than the Rutherfordton soil. Its composition is shown in Table 99.

[20] The author did not collect this sample and has not seen the topographic situation of the spot where it was collected.
[21] The two samples from the northern piedmont, one from Maryland, the other from Virginia, are not members of the Cecil series.

TABLE 99.—*Composition of Cecil fine sandy loam, Brooks Cross Roads, Yadkin County, N. C.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
236901	A_1	0-1	[a]88.02	0.22	0.76	4.47	0.009	0.04	0.04	1.19	0.35	0.02	0.05	4.63	99.80	0.068	------
			[b]92.29	.23	.80	4.69	.009	.04	.04	1.25	.37	.02	.05	------	99.79	------	------
236902-3	A_2	1-7	[a]87.13	.54	1.40	5.63	.013	Tr.	.17	2.05	1.41	.04	.13	3.13	101.64	.070	------
			[b]89.93	.56	1.44	5.81	.013	Tr.	.18	2.12	1.46	.04	.13	------	101.68	------	------
236904-5	B_1	7-14	[a]69.49	.85	4.85	15.86	.013	Tr.	.26	1.52	1.16	.09	.13	7.21	101.43	.060	------
			[b]74.89	.92	5.22	17.07	.014	Tr.	.28	1.64	1.25	.10	.14	------	101.52	------	------
236906	B_2	14-40	[a]34.24	1.31	11.18	35.42	.013	Tr.	.17	.62	.73	.18	.10	17.07	101.03	.040	------
			[b]41.21	1.58	13.46	42.63	.016	Tr.	.20	.75	.88	.22	.12	------	101.07	------	------
236907	C	40+	[a]49.62	.80	8.43	27.45	.020	Tr.	.63	2.08	1.04	.09	.12	10.74	100.02	.020	------
			[b]55.54	.90	9.44	30.72	.020	Tr.	.71	2.33	1.17	.10	.13	------	100.06	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
236902-3	A_2	1-7	7.6	13.8	7.1	37.1	10.8	16.5	7.6	100.6
236904-5	B_1	7-14	3.9	9.6	5.0	22.7	7.4	17.6	34.0	100.2
236906	B_2	14-40	.7	3.2	1.8	6.4	2.6	13.2	72.4	100.1
236907	C	40+	3.4	6.8	3.0	15.4	4.8	14.8	52.2	100.4

[1] Collected by W. D. Lee. [2] Analyzed by G. J. Hough and G. Edgington. [3] Analyzed by V. Jacquot.

The C horizon in this profile includes material more thoroughly decomposed and leached than in the two Cecil samples previously described. Only the upper part of horizon C was sampled. The minerals, except plates of mica, are decomposed beyond recognition by the unaided eye, and the horizon seems to contain a great deal of clay. The percentage of clay in horizon C is more than 50, whereas that in the deepest part of the Green Hill sample (Table 97) is only 8 and in the Rutherfordton sample (table 94), between 72 and 96 inches, is 14.

The percentage of CaO has been reduced to a trace, while in the lowest horizon of the Green Hill profile it was 1.09, though in the horizons above this it had been reduced to a trace. The percentage of potash is low for all horizons of the solum, being lowest of all in B_2 where the percentages of alumina and clay are highest. The percentage of potash in C, however, is 2.33, showing the results of the mica present. The percentage in A_2 is higher than in any other horizon of the solum, expressing the concentration of the micas by the removal of alumina and iron oxide through eluviation. Alumina and iron oxide are both low in A_1 and A_2, much lower than in the Rutherfordton profile of Cecil fine sandy loam. Silica is correspondingly high. Ignition loss in B_2 is higher than in the corresponding horizon of Cecil clay loam at Green Hill, N. C., but the alumina also is higher.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 100.

TABLE 100.—*Cecil fine sandy loam, Brooks Cross Roads, Yadkin County, N. C.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
236902 236903	A_2	1-7	26.30	165.50	0.809	1.49	0.009	0.057	0.046
236906	B_2	14-40	1.64	8.10	.066	.68	.084	.417	.022
236907	C	40+	3.07	15.59	.201	.92	.059	.300	.043

These results are consistent in showing the well-defined features of a normal podzolic profile so far as the relations of silica, iron oxide, and alumina are concerned. Both iron oxide and alumina are concentrated in the B horizon and have been lost from A_2, the alumina in A_2 being only a little more than a fifth of that in C and the iron oxide in A_2 being only about one-seventh of that in C. The percentage of silica is much higher in A_2 than in either B_2 or C.

The sa ratios show that the alumina in B_2, relative to silica, is nearly twice that in C. The sf ratios show almost the same relationships of iron oxide in the two horizons. The alumina-iron oxide ratios in the two horizons, 5.07 in C and 4.2 in B_2, show that iron oxide, relative to silica, has accumulated in B to a greater extent than alumina, but the difference is by no means so great as in the Green Hill, N. C., profile. This is in line with what has already been said about this sample (Brooks Cross Roads). The material here designated as C horizon material is from the top of C only, where it is grading into B_2. The accumulation of iron oxide in B_2 is greater, however, than that of alumina. The molecular equivalent composition shows accumulation of both iron and alumina and loss of silica in B_2.

The molecular equivalent composition of the combined alkalies and CaO shows that, although the sample from the C horizon does not extend to considerable depth, the B_2 horizon has only half the amount contained in C.

The composition of a Cecil sandy loam profile from Anderson County, S. C., is shown in Table 101.

TABLE 101.—*Composition of Cecil sandy loam, Anderson County, S. C.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
32365	A_1	0-2	[a]84.34	0.42	1.37	5.05	0.047	0.12	0.01	0.64	0.42	0.03	0.03	7.48	99.96	0.119	------
			[b]91.15	.45	1.48	5.46	.051	.13	.01	.69	.45	.03	.03	------	99.93	------	------
32366	A_2	2-9	[a]86.15	.53	1.56	6.33	.032	Tr.	.08	.77	.39	.03	.03	4.18	100.08	.042	------
			[b]89.90	.55	1.63	6.61	.033	Tr.	.08	.80	.41	.03	.03	------	100.07	------	------
32367-8	B	10-90	[a]52.03	1.24	9.23	25.55	.044	Tr.	.42	1.10	.42	.11	.03	10.32	100.49	.020	------
			[b]58.00	1.38	10.29	28.49	.049	Tr.	.47	1.23	.47	.12	.03	------	100.53	------	------
32369	C_1	91-150	[a]56.33	.92	7.12	24.24	.054	Tr.	.83	2.02	.39	.12	.01	8.47	100.50	.050	------
			[b]61.53	1.00	7.78	26.48	.059	Tr.	.91	2.21	.43	.13	.01	------	100.54	------	------
32370-2	C_2	151-270	[a]69.85	.57	3.87	17.19	.145	Tr.	.63	2.26	.41	.09	Tr.	5.46	100.48	.003	------
			[b]73.91	.60	4.09	18.18	.153	Tr.	.67	2.39	.43	.10	Tr.	------	101.52	------	------

[1] Collected by Mark Baldwin and E. D. Fowler. [2] Analyzed by G. Edgington.

TABLE 101.—*Composition of Cecil sandy loam, Anderson County, S. C.*—Continued

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
32365	A_1	0-2	8.4	31.3	7.4	16.1	4.2	20.8	11.8	100.0
32366	A_2	2-9	11.2	23.6	6.6	15.5	6.6	28.4	8.0	99.9
32367-8	B	10-90	1.4	7.9	3.3	8.4	2.8	29.2	46.8	99.8
32369	C_1	91-150	1.5	8.9	3.2	8.6	2.4	52.9	22.6	100.1
32370-2	C_2	151-270	7.2	15.2	4.2	10.2	4.4	47.8	10.7	99.9

[3] Analyzed by J. B. Spencer.

This is another typical Cecil profile developed under good drainage and not mutilated by erosion. The differentiation of the solum into A and B horizons is well marked. The A_2 horizon is yellow and sandy, the percentage of sand, shown by its mechanical composition in Table 101, of all grades being about 50, and of clay only 8. The B horizon is red, contains about 20 per cent sand of all grades, and in the upper part, 55 per cent clay. The C_2 horizon lies well down in the mass of disintegrated rock material and contains some undecomposed minerals. The percentage of clay is only 10.7, whereas that in B is 47 and in the upper part of B, not shown separately in the table, is 55. The texture differences between the horizons are very large. The maximum percentage of alumina in B is less than in the preceding Cecil profiles, and the same is true of iron oxide. The percentage of sand in each, B_1 and B_2, is nearly 60, whereas that in the Brooks Cross Roads profile (Table 99) is more than 65, but in the clay loam from Green Hill, N. C., it is a little more than 40.

The calcium content, like that in the Cecil profiles already examined, is extremely low, having been reduced to a trace even to a depth of more than 20 feet.

The content of potash, however, is high in C_2 but low in A_1 and A_2. The content of Na_2O is low throughout. The loss on ignition, which in the B horizon measures approximately the content of combined water, is practically the same as in the preceding profiles of Cecil soils, around 10 per cent, except in the Brooks Cross Roads, N. C., profile, where it amounts to a maximum of 17 per cent.

The several ratios and the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3 and the sum of the separate molecular equivalents of the alkalies and alkaline earths are shown in Table 102.

TABLE 102.—*Cecil sandy loam, Anderson County, S. C.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
32366	A_2	2-9	23.27	146.0	0.323	1.49	0.010	0.064	0.015
32367 32368	B	10-90	3.46	15.0	.106	.96	.064	.278	.020
32370 32371 32372	C_2	151-270	6.90	48.0	.278	1.22	.025	.178	.032

The sa ratio in horizon B is half that in C_2. That this is not due to accumulation of alumina in B alone is probable on the basis of the appearance of materials from the two horizons. Horizon C_2 contains a considerable percentage of undecomposed minerals. The molecular equivalent composition of silica shows that loss of silica has taken place in B, but the proportion of loss over that in C_2 is much less than would be necessary to account for the total difference in sa ratios between B and C_2, on the basis of loss of silica alone. The sa differences are due, therefore, both to loss of silica and accumulation of alumina, but the former has been small compared to the latter. The relative number of alumina molecules in B is practically 50 per cent more than in C_2.

The sf ratio for B is less than a third as large as in C_2, indicating that the iron oxide in B is three times as much as in C_2. The loss of silica, which has reduced the indicated accumulation of alumina in B, acts in the same way with respect to the iron oxide. The molecular equivalent composition shows the number of molecules of iron oxide in B to be almost three times the number in C_2. The number of alumina molecules in this horizon is less than twice that in C_2. It is clear that alumina and iron oxide have both been accumulated in B and have been removed from A_1 and A_2, but that iron oxide has increased in B more than alumina. This is shown also by the alumina-iron oxide ratios of 4.3 and 6.9, respectively, in horizons B and C_2.

The total quantities of alkalies and lime, in proportion to alumina, are greater in A_2 than in C_2, but the actual quantities per unit of weight of material, as shown by the molecular equivalent composition, are smaller in A_2 than in either B or C_2. The relative number of mo.ecules in B is 50 per cent less than in C_2, while those in A^2 are less than half those in C_2 and 30 per cent less than those in B.

The composition of material from the various horizons of another profile of Cecil sandy loam, from Milner, Lamar County, Ga., is shown in Table 103.

TABLE 103.—*Composition of Cecil sandy loam, Milner, Lamar County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
257806	A_1	0-2	[a]81.82	0.46	1.07	5.21	0.02	0.04	0.02	0.63	0.23	0.06	0.07	10.56	100.19	0.173	------
			[b]91.49	.51	1.20	5.82	.02	.04	.02	.70	.26	.07	.08	------	100.21	------	------
257807	A_2	2-9	[a]90.22	.49	.95	4.81	.02	Tr.	.01	.60	.16	.02	.05	2.38	99.71	.023	------
			[b]92.41	.50	.97	4.93	.02	Tr.	.01	.61	.16	.02	.05	------	99.68	------	------
257808	B	9-48	[a]56.47	.81	7.44	25.39	.02	Tr.	.03	1.28	.20	.06	.08	8.52	100.30	.011	------
			[b]61.72	.89	8.13	27.74	.02	Tr.	.03	1.40	.22	.07	.09	------	100.31	------	------
257809	C	48-65	[a]55.95	.85	7.95	25.20	.02	Tr.	.12	2.31	.24	.08	.07	7.28	100.07	.007	------
			[b]60.33	.92	8.58	27.18	.02	Tr.	.13	2.49	.26	.09	.08	------	100.07	------	------

[1] Collected by S. O. Perkins.
[2] Analyzed by G. Edgington.

Table 103.—*Composition of Cecil sandy loam, Milner, Lamar County, Ga.*—Continued

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
257806	A_1	0- 2	6.5	24.4	9.6	22.9	10.3	20.4	6.7	100.8
257807	A_2	2- 9	5.4	23.4	10.4	26.6	10.4	21.4	3.1	99.7
257808	B	9-48	2.2	10.7	4.2	10.4	5.6	26.6	40.5	100.2
257809	C	48-65	3.1	11.0	4.4	15.4	12.4	30.6	23.2	100.1

[3] Analyzed by J. B. Spencer and V. Jacquot.

This soil is a well-developed sandy loam with well-marked differentiation of A and B horizons, but the depth of sampling was not sufficient to reach undecomposed material. The upper part of the C horizon, extending from 48 to 65 inches, consists of rather well decomposed material but with a considerable mica content. The lime has been leached to a trace from all the horizons except a very small amount in A_1, where it is probably present in the organic matter. The higher percentage of potash in C than in the other horizons shows the presence either of undecomposed minerals or of a more active colloid than in A and B. There may be some suggestion that the latter is the true explanation in the low percentage of Na_2O, the amount being very little more than in B.

The probability of the presence of a more active colloid is rendered very slight by the results obtained by Holmes and Edgington (*10*). Of the 17 profiles of Cecil soils, the colloid materials of which were examined by them, 8 included material from the C horizon. Their definition of the C horizon is identical with that used in defining the C horizon from the Milner County, Ga., sample, and their results will apply to the latter. In no case was the C horizon colloid essentially more active than that of the B horizon.

The sample from Decatur, De Kalb County, Ga. (Table 104), is a typical fine sandy loam, but even at a depth of 9 feet from the surface the material is well leached.

Table 104.—*Composition of Cecil fine sandy loam, Decatur, De Kalb County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
30263	A_1	½- 4	[a]84.59	0.80	3.63	6.92	0.02	0.10	0.40	1.04	0.24	0.21	------	2.45	100.40	------	------
			[b]86.69	.82	3.72	7.09	.02	.10	.41	1.07	.25	.22	------	------	100.39	------	------
30266	B_1	17- 22	[a]64.56	.96	7.15	18.54	.02	.06	.22	1.16	.28	.26	------	6.81	100.02	------	------
			[b]69.29	1.03	7.67	19.89	.02	.06	.24	1.24	.30	.28	------	------	100.14	------	------
30269	C_1	86-120	[a]62.73	.71	7.46	19.26	.10	.08	1.22	1.00	.26	.29	------	7.67	100.78	------	------
			[b]67.94	.77	8.08	20.86	.11	.09	1.32	1.08	.28	.31	------	------	100.84	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
30263	A_1	½- 4	6.8	14.2	7.4	33.4	15.0	13.0	10.3	100.1
30264	A_2	5- 8	6.5	11.0	7.2	34.4	15.6	16.7	8.7	100.1
30265	A_3	9- 16	3.8	10.6	6.0	28.2	12.8	21.0	17.7	100.1
30266	B_1	17- 22	3.4	7.6	4.4	20.4	9.7	17.1	37.5	100.1
30267	B_2	23- 62	1.2	4.8	2.4	11.2	6.6	19.0	54.8	100.0
30268	B_3	63- 85	1.2	5.0	3.6	25.5	10.4	23.3	31.1	100.1
30269	C_1	86-120	3.7	11.8	8.6	41.2	12.2	15.7	6.8	100.0
30270	C_2	120-168	1.5	11.9	9.5	43.0	15.0	16.3	2.8	100.0

[1] Collected by Mark Baldwin.
[2] Analyzed by I. A. Denison.
[3] Analyzed by A. A. White and J. B. Spencer.

The characteristics of the profile are not well brought out by the chemical composition. The mechanical analysis shows the composition of all the horizons and subhorizons that were separately sampled. It shows that the layer between depths of 23 and 62 inches contains 54.8 per cent of clay, while the layer between 17 and 22 inches, the layer for which a chemical analysis was made, contains 37.5 per cent. A chemical analysis was not made of the true B horizon. The percentage of alumina in A is higher than in the previously examined Cecil fine sandy loam profiles, except the Rutherfordton profile. The mechanical analysis shows that the material is rather well decomposed to a depth of 85 inches. The horizon extending from 7 to 10 feet, however, contains only 7 per cent of clay, indicating a stage of disintegration rather than of decomposition of the minerals. The high percentage of alumina in this horizon shows the presence of aluminum-bearing minerals.

The composition of a sample of Cecil fine sandy loam from Lula, Ga., is shown in Table 105.

Table 105.—*Composition of Cecil fine sandy loam, Lula, Hall County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28911	A	2- 10	[a]89.89	0.61	1.23	4.49	0.017	0.04	0.01	0.82	0.12	0.01	0.04	2.52	99.80	0.029	------
			[b]92.21	.63	1.26	4.61	.017	.04	.01	.84	.12	.01	.04	------	99.79	------	------
28912	B	12- 40	[a]57.59	.49	5.63	24.95	.016	.30	.77	1.11	.11	.02	.11	9.25	100.35	.008	------
			[b]63.45	.54	6.20	27.49	.018	.33	.85	1.22	.12	.02	.12	------	100.36	------	------
28913	C_1	40- 60	[a]64.31	.39	4.17	21.06	.016	.28	.32	1.31	.02	Tr.	.06	8.15	100.09	.007	------
			[b]70.02	.42	4.54	22.93	.017	.30	.35	1.43	.02	Tr.	.07	------	100.10	------	------
28914	C_2	60-100	[a]66.50	.29	3.37	20.64	.020	.30	.44	1.80	.04	.01	.05	6.93	100.39	.006	------
			[b]71.45	.31	3.62	22.18	.020	.32	.47	1.93	.04	.01	.05	------	100.40	------	------
28915	C_3	150+	[a]68.64	.24	2.88	18.29	.034	.36	.76	3.12	.17	.04	.04	5.70	100.27	.002	------
			[b]72.79	.25	3.05	19.39	.036	.38	.81	3.31	.18	.04	.04	------	100.28	------	------

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough and G. Edgington.

Table 105.—*Composition of Cecil fine sandy loam, Lula, Hall County, Ga.*—Continued

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28911	A	2- 10	1.6	10.2	12.2	36.2	16.2	17.0	6.5	99.9
28912	B	12- 40	.5	6.6	4.5	16.8	9.5	23.3	38.8	100.0
28913	C_1	40- 60	2.0	10.0	5.8	22.0	12.6	24.1	23.5	100.0
28914	C_2	60-100	1.9	12.0	6.7	28.7	12.2	25.3	13.2	100.0
28915	C_3	150+	5.4	25.3	12.8	34.2	11.4	7.5	3.3	99.9

[3] Analyzed by A. A. White.

The surface soil with 75 per cent of sand of all classes and only 6.5 per cent of clay is a very light textured sandy loam. The B horizon, however, has 39 per cent of clay and 62 per cent of silt and clay combined. From a depth of 40 inches downward the percentage of clay decreases to 3 at a depth of 12 feet, and at this depth the materials consist almost entirely of disintegrated rock.

This profile differs from most of the Cecil profiles already examined in the low percentage of iron oxide, the maximum being 6.2. The percentage of alumina in B, the maximum in the profile, is about an average of the profiles already examined.

The percentage of CaO is low but is present in all horizons higher than a mere trace. The percentage of potash is moderate to a depth of 8 feet. At 12 feet it is relatively high, 3.3 per cent, indicating the presence of undecomposed minerals.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 106.

Table 106.—*Cecil fine sandy loam, Lula, Hall County, Ga.*

Sample No.	Horizon	Depth in inches	Ratios: sa	sf	ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
28911	A	2-10	34.00	193.8	0.256	1.53	0.008	0.04	0.0115
28912	B	12-40	3.90	27.1	.077	1.05	.038	.27	.0207
28915	C_3	150+	6.38	63.2	.225	1.21	.019	.19	.0448

The percentage of alumina in proportion to silica in B is practically twice that in C_3, and that in A is only a fifth of that in C_3. The relative number of molecules of silica in B, however, is about 15 per cent less than in C_3, so that, as in the other Cecil profiles, a small part of this increase of alumina in B must be ascribed to loss of silica. The sf ratio in B is less than that in C_3. Since the loss of silica in B over that in C_3 affects both alumina and iron oxide to the same extent, it is clear that here again, as in the Cecil profiles already examined, iron oxide has accumulated in B to a greater extent than alumina. The maximum percentage of both is found in the same horizon rather than in different horizons or at different depths as was the case in some of the soils of the coastal plain.

The presence of half as many molecules of total alkalies and alkaline earths, except MgO, in A as in B with more than six times as many alumina molecules in B, per unit of weight in both cases, shows either that horizon A must contain undecomposed primary silicate minerals in greater quantity than B or that the alumina in B is not equally absorptive. It is improbable, though not impossible, that primary silicate minerals are present in A.

The chemical and mechanical composition of material from a profile of Cecil sandy loam from Mount Airy, Habersham County, Ga., are shown in Table 107. The composition of colloid from the B horizon is shown also.

Table 107.—*Composition of Cecil sandy loam, Mount Airy, Habersham County, Ga.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28917	A	0- 4	[a]83.19	0.91	2.58	6.91	0.049	Tr.	0.01	0.56	0.06	0.03	0.04	5.82	100.16	0.079	------
			[b]88.33	.97	2.74	7.34	.052	Tr.	.01	.59	.06	.03	.04	------	100.16	------	------
28918	B	6-30	[a]57.58	1.05	9.51	21.53	.040	Tr.	.09	.80	Tr.	.07	.11	8.99	99.77	.018	------
			[b]63.27	1.15	10.46	23.66	.044	Tr.	.10	.88	Tr.	.08	.12	------	99.76	------	------
			[c]28.25	.79	15.03	37.26	.100	0.16	.29	.29	.08	.13	.19	17.33	99.90	------	------
			[d]34.15	.96	18.18	45.12	.120	.19	.35	.35	.10	.16	.23	------	99.91	------	------
28919	C_1	40-65	[a]74.59	.68	4.18	14.66	.029	Tr.	.06	.82	.06	.06	.04	5.01	100.19	.005	------
			[b]78.52	.72	4.40	15.44	.031	Tr.	.06	.85	.06	.06	.04	------	100.18	------	------
28920	C	900+	[a]75.41	.81	3.87	12.60	.084	Tr.	1.76	2.89	.19	.04	.05	2.71	100.41	.001	------
			[b]77.50	.83	3.98	12.95	.086	Tr.	1.81	2.97	.20	.04	.05	------	100.42	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28917	A	0- 4	3.5	15.2	11.8	14.6	10.8	30.3	14.0	100.2
28918	B	6-30	3.2	9.2	5.5	16.3	5.6	21.5	38.8	100.1
28919	C_1	40-65	.4	9.8	11.4	37.6	10.8	22.4	7.8	100.2

[1] Collected by C. F. Marbut.
[2] Analyzed by G. Edgington.
[3] Analyzed by A. A. White.

The profile is well developed, although the A horizon is thin. The material in B is thoroughly decomposed; that in C_1 is loose, reddish, and contains considerable mica. The material at a depth of 75 feet is well disintegrated. Its comparatively high percentage of potash shows it is not thoroughly leached, but its calcium is leached to a trace.

The composition of the colloid furnishes a better index of the character of the decomposed material than does the composition of the whole soil, since the free quartz and probably other minerals of the unchanged rock are absent, entirely or almost so, from the colloid.

The percentage of clay in horizon A is 14 and of clay and silt is 44, indicating a probable subserial A. A thickness of only 4 inches points in the same direction. The percentages of clay in B of practically 40 and in C_1 of 8 show a well-developed podzolic profile.

The percentage of alumina in A is rather high for a Cecil sandy loam, being higher than in any of the previously examined sandy loams except the Rutherfordton profile. The percentage of iron oxide is high also. The maximum percentages of both alumina and iron oxide are found in the same horizon.

The rather high percentage of alumina at a depth of 75 feet, being nearly as high as that in C_1, expresses the presence of undecomposed aluminum silicate primary minerals.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 108.

TABLE 108.—*Cecil sandy loam, Mount Airy, Habersham County, Ga.*

Sample No.	Horizon	Depth in inches	Ratios: sa	sf	ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
28917	A	0–4	20.40	85.40	0.1006	1.460	0.017	0.072	0.0072
28918	B	6–30	4.54	16.00	.0403	1.050	.065	.231	.0094
28919	C_1	40–65	8.64	47.29	.0661	1.308	.027	.151	.0100

The sa ratio in B is a very little more than half that in C_1, a relationship that has prevailed in several of the Cecil profiles already examined. The relative number of molecules of silica in B is, however, about 20 per cent smaller than the number in C_1, indicating, when considered in connection with the high alumina in B, that the ratio of silica to alumina is low.

The sf ratio in B is practically a third of that in C_1, showing again a greater accumulation of iron oxide than of alumina in B. This is confirmed by the alumina-iron oxide ratios 3.52 and 5.5 in B and C_1, respectively.

The sa, sf, and ba ratios of the colloid material in the B horizon (Table 107) are 1.28, 4.98, and 0.02, respectively. The low value for sa indicates the presence of free alumina, on the assumption that all the silica is combined with alumina in the molecular ratio of 2 to 1, that required for kaolin. On this assumption the silica present requires but 28.9 per cent of alumina. The actual content is 45 per cent. It is clear, therefore, that either free alumina is present or that an aluminum-silicate mineral of a lower sa ratio than 2 exists in this soil.

The chemical and mechanical composition of material from a profile of Cecil clay loam from Lanett, Chambers County, Ala., are shown in Table 109, along with the composition of colloid extracted from horizons A, B_1, and B_2 and analyzed by Holmes and Edgington (*10*) in the laboratories of the Bureau of Chemistry and Soils.

TABLE 109.—*Composition of Cecil clay loam, Lanett, Chambers County, Ala.*[1]

Sample No.	Horizon	Depth	Chemical[2]: SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
32352	A	0–7	[a]67.15	2.10	9.48	11.26	0.10	Tr.	0.71	1.02	0.40	0.16	0.10	8.65	101.13	0.100	------
			[b]73.50	2.29	10.36	12.32	.11	Tr.	.78	1.12	.44	.18	.11	------	101.21	------	------
			[c]35.18	1.00	12.84	35.80	.17	0.29	.45	.30	.05	.25	.10	13.24	99.67	------	------
			[d]40.70	1.16	14.83	41.41	.20	.34	.52	.35	.06	.29	.12	------	99.98	------	------
32353	B_1	8–24	[a]53.06	1.63	11.55	21.01	.07	Tr.	1.02	1.26	.34	.14	.09	10.08	100.25	.020	------
			[b]59.00	1.81	12.84	23.37	.08	Tr.	1.13	1.40	.38	.16	.10	------	100.27	------	------
			[c]34.25	1.15	15.20	34.47	.10	.08	.18	.30	.07	.04	.39	13.84	100.07	------	------
			[d]39.71	1.35	17.63	39.95	.12	.09	.21	.35	.08	.05	.45	------	100.99	------	------
32354	B_2	25–59	[a]52.51	1.34	11.66	22.10	.07	Tr.	1.80	2.12	.33	.15	.08	8.72	100.88	.002	------
			[b]57.52	1.47	12.77	24.20	.08	Tr.	1.98	2.32	.36	.16	.09	------	100.95	------	------
			[c]36.09	.76	14.85	34.12	.20	.02	.07	.37	.17	.04	.35	12.57	99.61	------	------
			[d]41.46	.87	17.05	39.20	.23	.03	.08	.42	.20	.05	.40	------	99.99	------	------
32357	C_2	241–300	[a]57.84	1.28	9.59	18.38	.17	Tr.	2.66	3.26	.31	.17	.03	6.47	100.16	.000	------
			[b]61.84	1.37	10.25	19.63	.18	Tr.	2.84	3.48	.33	.18	.03	------	100.19	------	------

Sample No.	Horizon	Depth	Mechanical[3]: Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
32352	A	0–7	0.8	9.6	5.5	12.9	4.8	44.1	22.3	100.0
32353	B_1	8–24	.6	5.6	3.0	8.0	7.7	22.3	52.8	100.0
32354	B_2	25–59	.1	5.4	2.8	5.7	3.2	41.5	41.3	100.0
32357	C	241–300	.2	7.8	4.2	11.5	5.6	52.3	18.4	100.0

[1] Collected by Mark Baldwin and E. D. Fowler.
[2] Analyzed by G. J. Hough.
[3] Analyzed by J. B. Spencer.

Being a clay loam the percentage of both silt and clay in horizon A is high, that of clay being 22 and of silt and clay 66. The percentage of clay in B_1 is 52 and in B_2 is 41, while the percentage of both silt and clay in B_1 is 75 and in B_2 is 82. The percentage of clay in C, at a depth ranging from 20 to 25 feet, is 18.4 and of both silt and clay is 70. The minerals are thoroughly disintegrated even at this depth. The percentages of alumina are high in A and C, in the latter being due to the presence of feldspathic minerals. The percentages in B_1 and B_2 are not so high, actually or relatively, as in some of the previously examined profiles. Calcium has been leached to a trace, but the percentages of potash and magnesia are both relatively high in the solum, especially in B_2, and especially high in C. The low percentage of Na_2O even in C suggests the presence of micas as the dominant silicate minerals rather than feldspars. This is suggested by the high percentage of silt in C and is confirmed by field evidence.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 110.

TABLE 110.—*Cecil clay loam, Lanett, Chambers County, Ala.*

Sample No.	Horizon	Depth in inches	Ratios: sa	sf	ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3
32352	A	0–7	10.14	18.80	0.16	1.218	0.065	0.120
32353	B_1	8–24	4.30	12.17	.09	.978	.080	.228
32354	B_2	25–59	4.04	11.93	.13	.953	.080	.237
32357	C_2	241–300	5.35	16.00	.19	1.025	.064	.192

The sa ratio for B_2, the lowest of the sa ratios, is less than 25 per cent lower than that of C. This is a much smaller difference than is present in the Cecil profiles previously examined where the B ratios have been practically half those in C. The sf ratio in B_2 is almost exactly 25 per cent lower than that in C. The alumina-iron oxide ratios also are almost exactly the same, being 2.95 and 2.98, respectively, for B_2 and C. The same relationship between the accumulation of iron oxide and alumina in B and C, as in the other Cecil profiles examined, is shown to exist but the difference is extremely small.

The composition of the colloid constitutes a part of Table 109. The percentage for each substance is fairly uniform throughout the profile. The percentage of iron oxide in the colloid of B_1 and B_2 is higher than that in the colloid of A, and the percentages of alumina and silica are correspondingly low.

Loss on ignition, which in B_1 and B_2 expresses mainly the content of combined water, is 13.84 in B_1 but a little lower in B_2. Alkalies and alkaline earths are low, but the percentage of CaO in A is more than 3 times that in B_1 and 14 times that in B_2.

The several ratios and the molecular equivalent composition in SiO_2, Fe_2O_3, and Al_2O_3 of the colloid of the Cecil clay loam from Lanett, Ala., are shown in Table 111.

TABLE 111.—*Colloid of Cecil clay loam, Lanett, Chambers County, Ala.*

Sample No.	Horizon	Depth in inches	Ratios: sa	sf	ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3
32352	A	0–7	1.67	7.25	0.026	0.734	0.101	0.441
32353	B_1	8–24	1.70	5.97	.017	.674	.119	.400
32354	B_2	25–59	1.80	6.44	.021	.700	.108	.380

The sa ratios of the colloid are progressively larger for A, B_1, and B_2, but the differences are small. These ratios for the colloid, like those in the Red soils from North Carolina southward, in all cases where colloid data are available, show the presence of free alumina. It is to be presumed that, had colloid composition data been available for the Yellow soils of the coastal plain, the same or a similar ratio would have been found. The composition of colloid from one sample of Norfolk soil from North Carolina (B horizon) showed an sa ratio of almost exactly 2 (p. 47), but no data are available for soils south of that. The sa ratio for the Chester and Miami soils (pp. 33 and 36) is higher than 2.

The chemical composition of the A and B horizons of a Cecil clay loam from Washington, Wilkes County, Ga., and that of the colloid from B are shown in Table 112.

TABLE 112.—*Chemical composition of Cecil clay loam, Washington, Wilkes County, Ga.*[1] [2]

Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	0–9	[a]83.81	0.80	2.97	7.70	0.20	0.28	0.15	0.79	0.43	0.06	0.02	2.89	100.24	0.030	------
		[b]86.30	.82	3.06	7.93	.21	.29	.15	.81	.44	.06	.02	------	100.07	------	------
B	9–18	[a]75.68	.87	4.21	12.95	.17	.43	.14	.73	.24	.05	.02	5.50	100.98	.040	------
		[b]80.09	.92	4.45	13.70	.18	.45	.15	.77	.25	.05	.02	------	101.02	------	------
		[c]31.84	.53	10.04	38.28	.14	.35	.23	.46	.28	.11	.02	18.00	100.28	.110	------
		[d]38.83	.65	12.24	46.63	.17	.43	.23	.56	.34	.13	.02	------	100.33	------	------

[1] Collected by D. D. Long.
[2] Analyzed by W. O. Robinson and R. S. Holmes.

The sa ratio in the colloid of the B horizon is 1.41, standing well below that for kaolin and, in line with the other Cecil profiles for which data on colloid composition are available, shows the presence of free alumina.

The Georgeville soils are associated with the Cecil and developed under the same climatic and biologic environment, but from material accumulated from the decomposition of slates. The chemical and mechanical composition of material from a profile from Henrico, N. C., are shown in Table 113.

TABLE 113.—*Composition of Georgeville silty clay loam, Henrico, Northampton County, N. C.*[1]

Sample No.	Horizon	Depth	Chemical[2]: SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P .ct.*	*P. ct.*
236715	A	2–6	[a]69.46	0.81	5.10	15.09	0.020	0.04	0.21	1.23	0.19	0.08	0.05	7.40	99.68	0.050	------
			[b]75.02	.87	5.51	16.29	.020	.04	.23	1.33	.21	.09	.05	------	99.62	------	------
236716	B_1	6–34	[a]54.03	.66	8.30	25.97	.013	.30	.23	1.56	.26	.13	.04	8.86	100.35	.014	------
			[b]59.27	.72	9.13	28.48	.014	.33	.25	1.71	.29	.14	.04	------	100.37	------	------
236717	B_2	34–48	[a]58.96	.44	7.52	22.44	.013	.14	.21	1.73	.28	.14	.05	7.53	99.45	.008	------
			[b]63.78	.98	8.13	24.27	.014	.15	.23	1.87	.30	.15	.05	------	99.42	------	------
236718	C	48–60	[a]62.31	.97	6.11	20.26	.004	.22	.38	4.35	.30	.13	.04	4.67	99.74	.003	------
			[b]65.35	1.02	6.41	21.24	.004	.23	.40	4.56	.31	.14	.04	------	99.70	------	------

Sample No.	Horizon	Depth	Mechanical[3]: Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
236715	A	2–6	1.0	1.9	1.4	21.7	26.0	15.0	33.7	100.7
236716	B_1	6–34	.3	.9	.6	11.2	10.4	21.7	54.9	100.0
236717	B_2	34–48	.2	.8	.7	19.3	17.8	24.6	37.0	100.4
236718	C	48–60	.0	1.4	3.4	50.0	25.4	15.4	5.0	100.6

[1] Collected by W. D. Lee. [2] Analyzed by G. J. Hough. [3]Analyzed by J. B. Spencer.

The mechanical composition shows the presence of a very low percentage, in horizon A, of medium and coarse sand and a relatively high percentage of fine and very fine sand, nearly 48 per cent, and the same percentage of combined silt and clay with 33 per cent of clay. The percentage of fine and very fine sand in B_1 is less than half that in A, whereas that of silt and clay is 76 per cent and of clay alone is 55 per cent, nearly twice that in A. The percentage of fine sand in C, however, is 50 per cent and that of fine and very fine sand is 75, while that of combined silt and clay is only 20, that of clay alone being only 5.

The percentage of alumina is high throughout the profile, compared with the more sandy red soils, being 16.3 in A and 21 in C, but in B_1 it is 28.5. The percentages of iron oxide run about parallel with those of alumina.

The CaO percentage is low but higher than a trace, and that of potash is moderately high even in the solum, while that in C is very high, indicating the presence of potash-bearing minerals, such as muscovite.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 114.

TABLE 114.—*Georgeville silty clay loam, Henrico, Northampton County, N. C.*

Sample No.	Horizon	Depth in inches	Ratios: sa	Ratios: sf	Ratios: ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
236715	A	2– 6	7.83	36.08	0.114	1.244	0.0345	0.1594	0.0180
236716	B_1	6–34	3.47	17.20	.101	.983	.0509	.2786	.0287
236718	C	48–60	5.18	27.00	.276	1.083	.0401	.2078	.0570

The sa ratio for horizon B_1 is 33 per cent smaller than that for horizon C, but that for A is more than twice that for B_1 and 50 per cent larger than that for C. The sf ratio for B_1 is a very small fraction less than 33 per cent of that in C. The relative number of molecules of silica per unit of weight in B_1 is only 10 per cent less than in C. Since this difference affects sa and sf ratios alike, it is evident that these ratios would indicate an accumulation of both iron oxide and alumina in B_1. That both have been accumulated is confirmed by the alumina-iron oxide ratios in the two horizons, 4.86 and 5.17 for the B_1 and C horizons, respectively.

The loss of alkalies and alkaline earths throughout the solum has been considerable. The relative number of molecules in B_1 is almost exactly half that in C and in A is about 60 per cent of that in B_1. The ba ratios show, however, that the amount by weight in A in proportion to alumina is a little more than in B_1, but both are less than half that in C.

The chemical and mechanical composition of material from a profile of Georgeville silt loam from Thelma, Halifax County, N. C., are shown in Table 115.

TABLE 115.—*Composition of Georgeville silt loam, Thelma, Halifax County, N. C.*[1]

Sample No.	Horizon	Depth	Chemical[2]: SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
32616	A_1	0– 2	[a]80.16	0.72	2.18	6.40	0.028	Tr.	0.36	0.93	1.82	0.04	0.06	6.87	99.56	0.060	------
			[b]86.05	.77	2.34	6.87	.030	Tr.	.39	1.00	1.95	.04	.06	------	99.50	------	------
32617	A_2	2– 7	[a]80.32	.79	3.23	8.50	.024	Tr.	.41	1.35	1.55	.05	.07	4.94	101.23	.040	------
			[b]84.48	.83	3.40	8.94	.025	Tr.	.43	1.42	1.63	.05	.07	------	101.28	------	------
32618	B	7–30	[a]55.28	.61	9.08	23.94	.032	Tr.	.74	1.71	.30	.03	.06	8.30	100.08	.017	------
			[b]60.28	.67	9.90	26.11	.035	Tr.	.81	1.86	.33	.03	.07	------	100.10	------	------
32619	C_1	30–40	[a]58.12	.64	8.27	22.25	.038	Tr.	.83	2.51	.36	.03	.06	7.06	100.17	.009	------
			[b]62.55	.69	8.90	23.94	.041	Tr.	.89	2.70	.39	.03	.06	------	101.20	------	------
32620	C_2	40–50	[a]69.09	.49	4.92	16.47	.032	Tr.	.98	3.98	.36	.04	.04	3.79	100.19	.009	------
			[b]71.80	.51	5.11	17.12	.033	Tr.	1.02	4.14	.37	.04	.04	------	100.18	------	------

Sample No.	Horizon	Depth	Mechanical[3]: Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
32616	A_1	0– 2	1.0	6.0	4.2	13.8	8.2	55.8	10.8	99.8
32617	A_2	2– 7	1.2	4.6	3.7	11.6	7.4	57.1	14.2	99.8
32618	B	7–30	.0	.5	.5	3.0	4.4	45.7	45.8	99.9
32619	C_1	30–40	.0	.7	.6	2.5	6.0	61.6	28.3	99.7
32620	C_2	40–50	.0	.0	.0	1.4	7.0	84.6	6.9	99.9

[1] Collected by W. E. Hearn.
[2] Analyzed by G. J. Hough and G. Edgington.
[3] Analyzed by V. Jacquot.

The mechanical composition of horizons A_1 and A_2 is almost the same in both, the percentages of silt and clay combined, 66.6 and 71.3, respectively, being a little higher in A_2. Fine and very fine sand constitute most of the rest.

The percentage of silt and clay, combined, in horizon B amounts to 91.5, and fine and very fine sand, combined, amount to 7.4. The percentage of silt is very high in C_2, higher than in B, where it is 45.7, but the percentage of clay in C_2 is only 7. The high percentage of silt in C_2, taken in connection with the high content of potash in this horizon, points to the presence of potash mica. Alumina is relatively high in C_2 but not so high as in the Georgeville profile from Henrico County, N. C. The two profiles are essentially similar in character, however. The percentages of iron oxide and alumina in A_2 are 3.40 and 8.94, respectively, while those in A of the Henrico profile, constituting the A_2 horizon, since the thin surface layer in that profile is not included, are 5.51 and 16.29, respectively. Since the B and C_1 horizons are essentially alike in both samples, this wide difference between the A_2 horizons is striking. It is an expression of a well-developed profile, with a well-eluviated A_2 horizon in the Thelma profile and a subserial A_2 in the Henrico profile. The fully developed B horizons in both cases and their close identity in percentages of silica, alumina, and iron oxide, along with the highly similar parent material, leaves no other explanation tenable.

The Henrico profile has suffered partial removal of a former A horizon, and a new one is developing and in doing so has invaded the top of B.

The CaO has been leached to a trace from the Thelma profile, but the potash in the solum is present in moderate percentage, and in C it is high. Na_2O is unusually high in A.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 116.

TABLE 116.—*Georgeville silt loam, Thelma, Halifax County, N. C.*

Sample No.	Horizon	Depth in inches	Ratios: sa	Ratios: sf	Ratios: ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3
32617	A_2	2– 7	16.06	65.84	0.472	1.41	0.0213	0.087
32618	B	7–30	3.92	16.13	.098	1.00	.0620	.255
32620	C_2	40–50	7.13	37.23	.298	1.19	.0320	.167

The sa ratio for horizon B is a little less than half that for C_2, but that for A_2 is more than four times as great as that for B and more than twice that for C_2. This proportion differs widely from the ratios in the Henrico profile where that for A was only about 30 per cent less than that for C and only twice that for B_1. The explanation lies in the more thorough eluviation or the greater perfection of podzolic profile development. The sf ratio in C_2 of the Thelma profile is 2.3 times as large as that in B, and that in A_2 is four times as large. The relative number of molecules of silica, per unit of weight, in horizon C_2 is only one and one-fifth times the number in B. This is much less than the differences in sa and sf ratios in corresponding horizons, showing that accumulation of both alumina and iron oxide has taken place. The accumulation of iron oxide, however, has taken place to a greater extent than that of alumina, placing this profile of Georgeville soils in harmony with all the fully developed Red soils of the piedmont plateau so far examined. The alumina-iron oxide ratios for the B and C_2 horizons are 4.2 and 5.2, respectively.

The Georgeville soils have developed on slopes where oxidation is favored by rapid run-off. They are associated with the Alamance soils developed from the same materials but on smooth or level relief where drainage is not so complete or rapid. The latter are yellowish soils with a profile somewhat like that of the Norfolk soils. The Georgeville soil at Thelma has developed on a slope less steep than that on which the soil at Henrico developed. The soil at Thelma is not only more thoroughly eluviated but is more thoroughly leached, the lime having been leached to a trace.

COMPOSITION OF DURHAM, APPLING, AND PORTERS SOILS

Durham soils are associated with Cecil soils in the piedmont region of the Southern States, having developed from gneisses, in some cases granitic gneisses, but typical Durham soils have developed on smooth or nearly level uplands where drainage is not perfect.

The chemical and mechanical composition of material from a profile of Durham fine sandy loam from Reidsville, Rockingham County, N. C., are shown in Table 117. According to the results of the analyses, as well as to the field characteristics of the profile, this soil is podzolic and has a well-eluviated profile.

TABLE 117.—*Composition of Durham fine sandy loam, Reidsville, Rockingham County, N. C.*[1]

Sample No.	Horizon	Depth	Chemical[2]: SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
32381	A_1	0– 1	[a]75.83	0.21	1.07	9.64	0.051	0.07	0.02	5.05	0.97	0.03	0.06	6.91	99.91	0.125	------
			[b]81.46	.23	1.15	10.36	.055	.08	.02	5.43	1.04	.03	.06	------	99.92	------	------
32382	A_2	2– 12	[a]79.17	.23	1.60	9.89	.030	.70	.06	5.08	1.16	.06	.02	2.18	100.18	.030	------
			[b]80.92	.24	1.64	10.11	.030	.72	.06	5.19	1.18	.06	.02	------	100.17	------	------
32383	B_1	13– 20	[a]61.46	.32	4.30	21.72	.020	.20	.10	3.53	1.04	.05	.03	7.57	100.34	.020	------
			[b]66.48	.35	4.65	23.51	.020	.22	.11	3.82	1.13	.05	.03	------	100.37	------	------
32384	B_2	21– 44	[a]65.22	.26	3.32	19.43	.030	.20	.07	4.45	1.70	.05	.01	6.02	100.76	.000	------
			[b]69.42	.28	3.53	20.68	.030	.21	.07	4.74	1.81	.05	.01	------	100.83	------	------
32386-8	C	61–180	[a]72.61	.19	2.08	14.78	.040	.26	.07	5.45	2.36	.03	.03	2.93	100.83	.000	------
			[b]74.79	.20	2.14	15.22	.040	.27	.07	5.61	2.43	.03	.03	------	100.83	------	------

Sample No.	Horizon	Depth	Mechanical[3]: Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
32381	A_1	0– 1	0.3	5.2	6.4	29.9	11.4	39.6	7.3	100.1
32382	A_2	2– 12	.4	5.1	4.4	20.7	12.0	43.9	13.5	100.0
32383	B_1	13– 20	.0	1.8	2.2	11.4	6.8	50.5	27.2	99.9
32384	B_2	21– 44	.2	3.1	3.2	16.8	10.3	32.5	33.8	99.9
32386-8	C	61–180	.5	7.3	5.3	24.1	16.0	40.5	6.9	100.6

[1] Collected by Mark Baldwin and E. D. Fowler.
[2] Analyzed by G. Edgington.
[3] Analyzed by J. B. Spencer.

The percentage of clay in the thin 1-inch surface layer is 7, but the silt percentage is 40. The sand is mainly fine and very fine. Horizon B_1 has a total silt and clay content of 78 and B_2 of 66, but the clay percentage alone is a little higher in B_2 than in B_1. Silt percentage is high in horizon C amounting to 40.5, but the clay content is only 7 per cent. The sand in C is largely fine and very fine, the percentage of the latter lying between those of fine sand and silt. Medium and coarse sand are present in small amounts.

The percentage of iron oxide is low throughout the profile, the maximum in horizon B_1 being 4.65. The percentage of silica is much higher than in the Henrico profile of the Georgeville soil and somewhat higher than in the well-eluviated Thelma sample of the same soil. The percentage of alumina throughout the profile is moderately high, that in C being 15.2, showing the presence of feldspathic or mica minerals. The potash percentage is very high throughout the profile and that of Na_2O is moderately high. The percentages of potash in A_1 and A_2 are as high as in C, suggesting the presence of potash mica. The percentage of CaO is low but more than a trace.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 118.

TABLE 118.—*Durham fine sandy loam, Reidsville, Rockingham County, N.C.*

Sample No.	Horizon	Depth in inches	Ratios: sa	Ratios: sf	Ratios: ba	Molecular equivalent composition: SiO_2	Molecular equivalent composition: Fe_2O_3	Molecular equivalent composition: Al_2O_3	Molecular equivalent composition: Alkalies and alkaline earths
32382	A_2	2- 12	13.60	130.50	0.878	1.34	0.0103	0.099	0.0871
32383	B_1	13- 20	4.80	37.88	.272	1.10	.0291	1.470	.0627
32386, 32387, 32388	C	61-180	8.35	92.60	.695	1.24	.0134	.095	.1037

The sa ratio in horizon B_1 is about 60 per cent as large as in C, and that in A_2 is nearly three times that in B_1. Notwithstanding the high percentage of potash in A_1 and A_2, it is evident that the podzolic profile is mature or at least the profile is well eluviated. The difference between the number of silica molecules in C and B_1 is not large, only 10 per cent more in C than in B_1. The sf ratio in B_1 is only 40 per cent as large as that in C, making it evident that iron oxide has accumulated in B to a greater extent than alumina, bringing this soil, although not red and carrying a low percentage of iron oxide, into harmony in this respect with the Red soils. The alumina-iron oxide ratios in B_1 and C are 7.88 and 11.1, respectively. The high ba ratio in A_2 is noticeable in view of the relatively small difference in sa ratios between A_2 and B_1. In the highly eluviated sandy Cecil soils where the differences between sa in A and B are very high, that in A being eight times that in B, the ba ratio in A has amounted to as much as three and one-half times that in B. In the Reidsville Durham soil the explanation seems to lie in the presence of undecomposed primary minerals.

The wide difference between the ba ratios in B_1 and C are not maintained in the molecular equivalent composition of the combined alkalies and lime, the former ratios being influenced as much by the different amounts of alumina as by those of the alkalies and lime, while the differences between the values, per unit of weight, for the molecular equivalent compositions are determined by the quantities present of the substances themselves. The differences are high in molecular equivalent quantities, however.

The chemical and mechanical composition of material from a profile of Durham sandy loam at Stone Mountain, Ga., are shown in Table 119.

TABLE 119.—*Composition of Durham sandy loam, Stone Mountain, Ga.* [1]

Sample No.	Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
			Chemical [2]														
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
30254	A	0- 7	[a]79.33	0.15	1.02	10.87	0.02	0.33	0.06	5.15	1.01	0.26	------	2.28	100.48	------	------
			[b]81.18	.15	1.04	11.13	.02	.34	.06	5.27	1.03	.27	------	------	100.49	------	------
30258	B	51- 73	[a]68.28	.14	2.04	19.04	.02	.19	.24	4.94	.40	.15	------	4.91	100.35	------	------
			[b]71.81	.15	2.14	20.02	.02	.20	.25	5.20	.42	.16	------	------	100.37	------	------
30260	C_1	91-102	[a]70.51	.08	1.02	17.46	.02	.24	.18	6.22	.52	.32	------	3.85	100.42	------	------
			[b]73.33	.08	1.06	18.16	.02	.25	.19	6.47	.54	.33	------	------	100.43	------	------
	C_2	111+	[a]73.48	.12	.91	15.24	.03	.40	.34	4.28	4.46	.30	------	.61	100.17	------	------
			[b]73.93	.12	.92	15.33	.03	.40	.34	4.31	4.49	.30	------	------	100.17	------	------

Sample No.	Horizon	Depth	Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
			Mechanical [3]							
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
30254	A	0- 7	7.8	26.4	12.3	26.4	7.0	14.7	5.4	100.0
30258	B	51- 73	6.7	13.0	4.8	14.2	4.6	29.6	26.9	99.8
30260	C_1	91-102	11.3	31.2	12.1	22.9	6.4	12.8	3.2	99.9

[1] Collected by Mark Baldwin.
[2] Analyzed by I. A. Denison.
[3] Analyzed by A. C. White.

The percentage of coarse sand in horizon A in this profile is high, amounting to 26, being higher than in any profile in the piedmont plateau yet examined. The percentage of fine sand is 26 also, but that of very fine sand is only 7. The percentage of combined silt and clay in horizon A is 20, that of clay being 5. The percentage of combined silt and clay in B is 56.5, that of clay being 27. The sands are still mainly fine and coarse. Clay in C_1 amounts to 3 per cent only and silt to 12, while the percentage of coarse sand is 31 and of fine sand 23.

The percentage of iron oxide is low, lower than in the Reidsville profile of Durham soil, and the percentage of alumina is very close to that in the Reidsville profile. Potash is as high as in the Reidsville profile, being as high again in horizon A.

It is evident that the chemical, physical, morphological, and apparently the mineralogical features of this profile of Durham sandy loam are essentially the same as those of the Reidsville profile in all important respects except that of texture, as it contains more coarse sand. The ratios and molecular equivalent composition would not add anything more than is shown in Table 118.

Studies by Denison (*4*) of some of the horizons of the Durham soil from Stone Mountain, Ga., show an sa ratio in the colloid of C_1 of 1.65.

The Appling soils have developed on smooth relief in situations where drainage is not rapid enough to allow the thorough oxidation and dehydration necessary for producing the red color of the Cecil soils. In some cases induration of the upper C horizon or lower B has taken place also, owing, presumably, to the presence of ground water. They are essentially pale-colored Cecil soils with or without induration in B or C.

The chemical and mechanical composition of material from a profile of Appling sandy loam from Sandymush, N. C., are shown in Table 120. The characteristics of the Cecil profile are well shown except in the two respects of a relatively low percentage of iron oxide and a high percentage of alkalies. The content of lime is low but higher than in some of the Cecil soils where it is present as a trace only. The profile is well developed, the A horizon having high silica and low sesquioxides, while in the B horizon the reverse relation exists.

TABLE 120.—*Composition of Appling sandy loam, Sandymush, N. C.*[1]

Sample No.	Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from from carbonates
			Chemical [2]														
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
236515	A_1	0- 2	[a]88.58	0.29	1.21	3.74	0.008	0.26	0.04	1.28	1.45	0.05	0.03	4.50	101.43	0.160	------
			[b]92.75	.30	1.27	3.91	.008	.27	.04	1.34	1.52	.05	.03	------	101.49	------	------
236516	A_2	2- 8	[a]88.86	.44	1.36	5.25	.008	.24	.04	1.29	1.30	.04	.04	2.00	100.86	.040	------
			[b]90.68	.45	1.39	5.36	.008	.24	.04	1.32	1.33	.04	.04	------	100.90	------	------
236517	B_1	8-18	[a]49.30	.67	6.42	29.21	.008	.25	.20	1.06	1.29	.12	.10	11.81	100.44	.090	------
			[b]55.92	.76	7.28	33.11	.009	.27	.23	1.20	1.46	.14	.11	------	100.50	------	------
236518	B_2	18-40	[a]50.41	.61	6.26	29.52	.008	.29	.15	1.43	1.42	.09	.07	11.16	101.42	.030	------
			[b]56.74	.69	7.03	33.19	.009	.33	.17	1.61	1.60	.10	.08	------	101.55	------	------
236519	C_1	40-72	[a]61.60	.45	4.97	22.81	.018	.20	.16	1.87	1.59	.09	.08	7.17	101.00	.000	------
			[b]66.34	.48	5.35	24.56	.020	.22	.17	2.01	1.71	.10	.09	------	101.05	------	------
236520	C_2	72+	[a]68.14	.29	3.47	19.27	.013	.20	.16	2.14	1.36	.10	.07	6.27	101.48	.000	------
			[b]72.68	.31	3.70	20.54	.014	.21	.17	2.28	1.45	.11	.07	------	101.53	------	------

Sample No.	Horizon	Depth	Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
			Mechanical [3]							
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
236515	A_1	0- 2	14.8	26.0	8.4	23.4	8.4	12.3	6.9	100.2
236516	A_2	2- 8	21.2	21.4	6.7	18.8	8.2	15.4	8.5	100.2
236517	B_1	8-18	6.8	7.6	2.2	6.2	3.0	13.4	61.0	100.2
236518	B_2	18-40	5.0	7.4	2.3	7.0	3.6	14.8	60.0	100.1
236519	C_1	40-72	12.1	12.2	3.6	13.0	6.3	18.5	34.3	100.0
236520	C_2	72+	9.2	16.4	4.7	18.0	10.4	27.4	13.9	100.0

[1] Collected by R. C. Jurney.
[2] Analyzed by G. J. Hough.
[3] Analyzed by A. A. White.

Both the A_1 and A_2 layers of the A horizon contain more than 20 per cent each of coarse and fine sand and usually 15 per cent of fine gravel consisting of small pellets of iron oxide, an expression of imperfect drainage. The percentages of silt and clay are low, about 8 of clay and 14 of silt. Horizons B_1 and B_2 contain 60 per cent of clay but no greater percentage of silt than in A. The percentages of sand are low, and coarse and fine sand predominate. Clay is reduced to 14 per cent in C_2, but silt has risen to 27, and the percentage of sand has increased proportionately. The soil has a well-eluviated profile.

Iron oxide is higher than in the Durham profiles. Alumina is lower in A but a little higher in B and C. The potash content is much lower than in the Durham soils, the maximum percentage in the solum being 1.6 in B_2 and 2.28 in C_2. The percentage of Na_2O is rather high but not strikingly so. The calcium percentage is low, and that of silica in A is very high.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3 are shown in Table 121.

TABLE 121.—*Appling sandy loam, Sandymush, N. C.*

Sample No.	Horizon	Depth in inches	Ratios: sa	Ratios: sf	Ratios: ba	Molecular equivalent composition: SiO_2	Molecular equivalent composition: Fe_2O_3	Molecular equivalent composition: Al_2O_3
236516	A_2	2- 8	28.76	172.80	0.757	1.500	0.0087	0.0524
236518	B_2	18-40	2.90	21.38	.150	.941	.0440	.3240
236520	C_2	72+	6.01	50.28	.255	1.200	.0232	.2010

As in many of the piedmont-plateau soils in the Red soil region, the sa ratio in B_2 is almost exactly half that in C_2, which would signify twice the amount of alumina per unit of weight in B_2, or an accumulation of 100 per cent if no change in silica or volume had taken place. The relative number of molecules of silica in B_2 is only 20 per cent less than in C_2. The loss of silica, as in the other Red soils or in the Podzolic soils generally, has not been sufficient to account for the apparent accumulation of alumina. The increase or accumulation of the latter in B_2 is apparently more than twice as much as would be indicated in the sa ratio because of loss of silica.

The sf ratio in C_2 is more than twice that in B_2, again showing a greater accumulation of iron in B_2 than of alumina. The alumina-iron oxide ratios in B_2 and C_2 are 7.3 and 8.6, respectively. Notwithstanding the occurrence of this soil on a nearly flat surface and its subjection to ground water at a slight depth, it has a well-developed podzolic profile. It seems to have developed under the same conditions as those under which the Norfolk soils have developed. They are both yellow or yellowish soils.

The chemical and mechanical composition of material from another profile of Appling sandy loam from Milner, Lamar County, Ga., are shown in Table 122. It was not sampled to so great a depth as the Sandymush profile, the deepest horizon barely reaching C. It differs from the Sandymush soil in the presence of a lower percentage of alkalies and CaO which may be due either to difference of parent materials or to more thorough leaching in the more southerly locality. Eluviation is about as clearly shown as in the Sandymush soil, the sesquioxides being present in much higher percentages in B than in A. No studies of the colloid from either profile have been made.

TABLE 122.—*Composition of Appling sandy loam, Milner, Lamar County, Ga.*[1]

Sample No.	Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
			Chemical [2]														
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
257801	A_1	0- 3	[a]89.45	0.39	0.75	4.48	0.040	(3)	(3)	0.45	0.14	0.08	0.03	3.82	99.63	0.061	------
			[b]93.00	.41	.78	4.66	.040	(3)	(3)	.47	.15	.08	.03	------	99.62	------	------
257802	A_2	3-10	[a]89.83	.47	.88	5.92	.010	(3)	0.16	.60	.23	.01	.02	2.02	100.15	.016	------
			[b]91.68	.48	.90	6.04	.010	(3)	.16	.60	.23	.01	.02	------	100.13	------	------
257803	B^1	10-20	[a]61.13	.66	5.58	22.24	.009	0.10	.18	.71	.23	.03	.08	8.64	99.59	.006	------
			[b]66.91	.72	6.11	24.35	.010	.11	.20	.78	.25	.03	.09	------	99.56	------	------
257804	B_2	20-40	[a]60.04	.72	5.83	22.86	.010	.16	.11	.69	.16	.06	.04	8.97	99.65	.006	------
			[b]65.93	.79	6.42	25.10	.010	.18	.12	.76	.18	.07	.04	------	99.60	------	------
257805	C	40-60	[a]62.38	.59	4.04	23.19	.013	.10	.23	1.21	.12	.05	.04	8.16	100.12	.002	------
			[b]67.92	.64	4.40	25.24	.014	.11	.25	1.32	.13	.05	.04	------	100.11	------	------

[1] Collected by S. O. Perkins. [2] Analyzed by G. Edgington and G. J. Hough. [3] Trace.

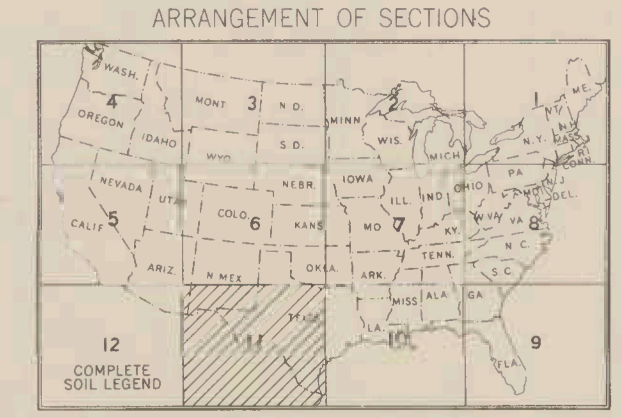
LEGEND FOR THIS SECTION

Abilene	Frio	McCammon	Springer
Aiken	Gila	Meeker	Springer sand
Amarillo	Harris	Miller	Trinity
Amarillo sand	Houston	Ochlockonee	Valera
Cahaba	Imperial	Otero	Vernon
Coronado	Katy	Pond	Victoria
Crawford	Kirkland	Kaibab	Windthorst
Deschutes	Lahontan	Reagan	Bad land
Durant	Lake Charles	Reeves	Marsh and Swamp
Duval	Lufkin	San Saba	Rough and Stony land
Elgin	Maverick	Sierra	Sand light
Hanceville	Encina	Susquehanna	Mohave

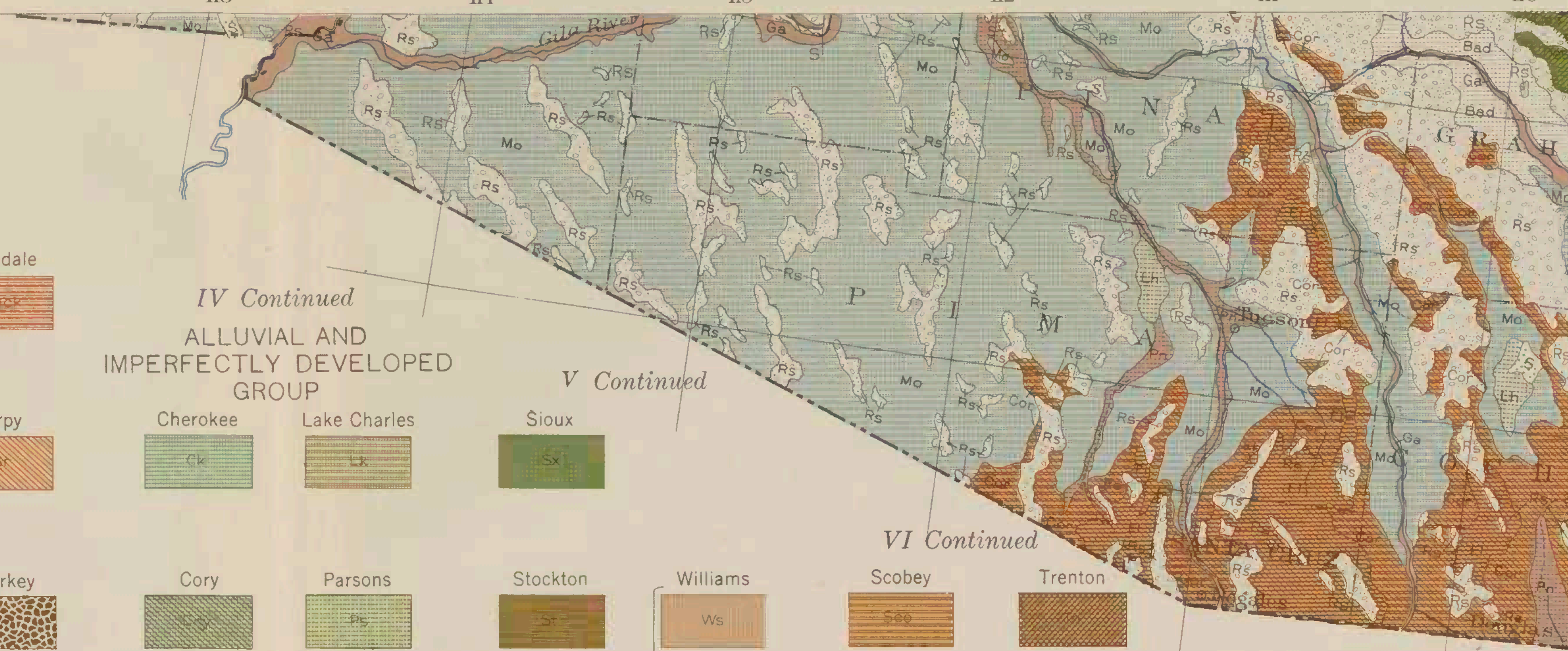
Desert vegetation on Guadalupe Mountains, Texas

Cotton on Amarillo sandy loam, near Spur, Dickens County, Tex.

ARRANGEMENT OF SECTIONS



Lith. A. Hoen & Co., Inc.



LEGEND

I PODZOL SOILS

- Caribou
- Ontonagon
- Colton
- sandy type
- Beltrami
- Rubicon
- Dekalb
- Spencer
- sandy type
- Summerville
- Hermon
- heavy type

II GRAY-BROWN PODZOLIC SOILS

WELL DEVELOPED GROUP

- Altamont
- Dutchess
- Baxter
- Elk
- Boone
- Everett
- Chester
- Fortine
- Clarksville
- Fox
- Clinton
- Gibson
- Collington
- Gloucester
- Dover
- Hagerstown
- Dunkirk
- Helmer

II Continued

- Kaibab
- Ontario
- Knox
- sandy type
- Lackawanna
- Penn
- Lebanon
- sandy type
- Leonard-town
- Plainfield
- Lindley
- Sassafras
- Lordstown
- Springdale
- Lowell
- Superior
- Manor
- sandy type
- Merrimac
- Tilsit
- Melbourne
- Upshur
- Miami
- Vergennes
- sandy type
- Wethersfield
- Moscow
- Wooster
- Nason
- Worth
- sandy type

II Continued ALLUVIAL AND IMPERFECTLY DEVELOPED GROUP

- Amity
- Meigs
- Clermont
- Muskingum
- Clyde
- sandy type
- Colville
- Sacramento
- Crosby
- sandy type
- Fairmount
- Toutle
- Genesee
- Volusia
- Hanford
- Westmore-land
- Huntington
- Willamette

III RED AND YELLOW SOILS

WELL DEVELOPED GROUP

Red members:
- Aiken
- Cahaba
- Cecil
- sandy type
- Davidson

Yellow members:
- Alamance
- Caddo
- Conway
- Durham
- Fellowship

III Continued

Red members:
- Decatur
- Georgeville
- Hanceville
- sandy type
- Louisa
- Oktibbeha
- Orangeburg
- Placentia
- Ruston
- Sierra

Yellow members:
- Grenada
- Hartsells
- sandy type
- Memphis
- Norfolk
- Susquehanna
- sandy type
- Talladega
- Tifton

III Continued

- Ochlockonee
- Rockdale
- Olivier
- Sarpy
- Parkwood dark phase
- Sharkey
- gray phase
- Trinity
- Plummer
- Waverly
- Portland
- Willows
- Portsmouth
- Yolo

III Continued ALLUVIAL AND IMPERFECTLY DEVELOPED GROUP

- Bladen
- Iredell
- Coxville
- Leon
- Crowley
- Lufkin
- Dublin
- Miller
- Houston
- Myatt

IV PRAIRIE SOILS

WELL DEVELOPED GROUP

- Bates
- Grundy
- Carrington
- Marshall
- Clarion
- San Saba
- Crawford
- Shelby
- Crete
- Spanaway
- Derby
- Summit
- Durant
- Waukesha
- Eldorado
- Windthorst

IV Continued ALLUVIAL AND IMPERFECTLY DEVELOPED GROUP

- Cherokee
- Lake Charles
- Cory
- Parsons
- Frio
- Putnam
- Harris
- Scott
- Katy
- Wabash
- Kirkland
- Webster

V CHERNOZEM SOILS

WELL DEVELOPED GROUP

- Abilene
- Duval
- Amarillo
- Hall
- sandy type
- Hays
- Barnes
- sandy type
- sandy type
- Holdrege
- Bearden
- Lewistown
- sandy type
- Moody
- Deschutes
- Palouse

V Continued

- Sioux
- Stockton
- Williams
- Victoria
- sandy type

V Continued ALLUVIAL AND IMPERFECTLY DEVELOPED GROUP

- Amarillo sand
- Vernon
- Fargo
- sandy type
- Valera

VI DARK-BROWN SOILS

WELL DEVELOPED GROUP

- Colby
- Maverick
- Coronado
- Meeker
- Daniels
- Rosebud
- gravelly type
- sandy type
- Elgin
- gravelly type
- Encina
- Springer
- Hyrum
- sandy type

VI Continued

- Scobey
- Trenton

VI Continued ALLUVIAL AND IMPERFECTLY DEVELOPED GROUP

- Antioch
- Pierre
- Dawes
- Reagan
- Laurel
- Springer sand
- Phillips
- Valentine

VII BROWN SOILS

- Bridger
- Otero
- Capay
- Portneuf
- Grantsdale
- Ritzville
- Joplin

VIII GRAY DESERT SOILS

WELL DEVELOPED GROUP

- Ephrata
- Fresno
- Jordan
- sandy type

VIII Continued

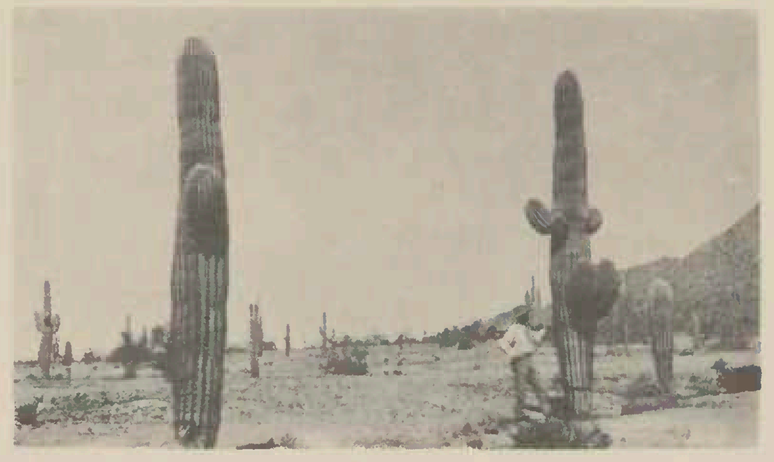
- Kettleman
- Panoche
- McCammon
- sandy type
- Mohave
- Quincy
- Onyx
- Reeves

VIII Continued ALLUVIAL AND IMPERFECTLY DEVELOPED GROUP

- Gila
- Lahontan
- Humboldt
- Pond
- Imperial
- San Joaquin
- sandy type
- Snake

UNDIFFERENTIATED

- Bad land
- Sand dark
- Peat and Muck
- light
- Marsh and Swamp
- Rough and Stony land



Giant cactus on desert (Mohave) soil, between alluvial fan and mountain, Maricopa County, Ariz.

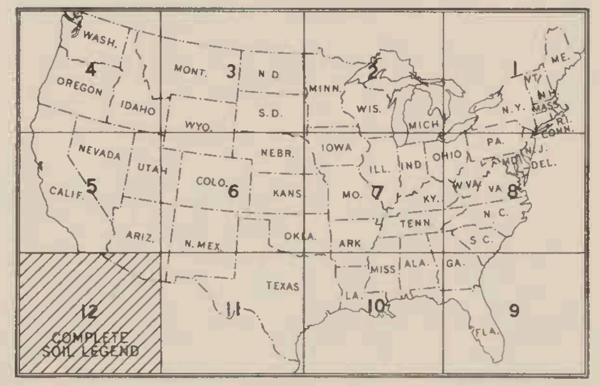
Natural vegetation (post oak) on Susquehanna fine sandy loam, Milam County, Tex.

Small farms on Knox silt loam on Missouri River bluff, Andrew County, Mo.

Farmstead on Hagerstown soils, Bedford County, Tenn.

Field of harvested corn on Hagerstown loam, Frederick County, Md.

ARRANGEMENT OF SECTIONS



Lith. A. Hoen & Co., Inc.

Table 122.—*Composition of Appling sandy loam, Milner, Lamar County, Ga.*—Continued

Sample No.	Horizon	Depth	Mechanical [4]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
257801	A_1	0–3	10.4	18.7	8.7	27.5	11.9	17.8	5.6	100.6
257802	A_2	3–10	8.1	8.9	8.8	27.8	12.5	18.7	15.9	100.7
257803	B_1	10–20	7.2	10.4	3.8	10.6	5.0	25.8	37.5	100.3
257804	B_2	20–40	6.1	9.8	3.6	11.4	6.5	28.7	34.2	100.3
257805	C	40–60	7.2	11.0	4.4	16.4	11.0	28.9	21.1	100.0

[4] Analyzed by J. B. Spencer and V. Jacquot.

The Porters soils occur in the Blue Ridge plateau of western North Carolina and northern Georgia. They are reddish soils, seemingly differing from the Cecil mainly in the degree of profile development.

The chemical and mechanical composition of material from a profile of Porters loam from Chimney Rock, N. C., are shown in Table 123.

Table 123.—*Composition of Porters loam, Chimney Rock, N.C.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
35000	A_1	0–4	[a]73.00	0.53	2.24	11.67	0.03	0.84	0.52	4.28	1.28	0.06	------	6.24	100.69	------	------
			[b]77.85	.57	2.39	12.44	.03	.90	.56	4.56	1.36	.06	------	------	100.72	------	------
35001	B	14–48	[a]60.34	.65	4.92	21.07	.04	.24	.80	3.14	.60	.08	------	8.02	99.90	------	------
			[b]65.61	.71	5.35	22.91	.04	.26	.87	3.42	.65	.09	------	------	99.91	------	------
35001A	C_1	72–96	[a]67.56	.56	3.52	16.54	.07	.28	.74	5.30	.84	.08	------	4.22	99.71	------	------
			[b]70.54	.59	3.67	17.27	.07	.29	.77	5.53	.88	.08	------	------	99.79	------	------
35001B	C_2	96+	[a]71.50	.39	2.72	14.21	.05	1.84	.61	4.52	2.84	.42	------	.44	99.54	------	------
			[b]71.79	.39	2.73	14.27	.05	1.85	.61	4.54	2.85	.42	------	------	99.50	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
35000	A_1	0–4	2.7	13.2	8.9	33.1	13.9	19.7	8.7	100.2
35001	B	14–48	2.2	6.4	4.4	23.7	11.8	8.4	43.4	100.3

[1] Collected by W. E. Hearn.
[2] Analyzed by I. A. Denison.
[3] Analyzed by J. B. Spencer.

The soil is identified as a loam rather than a sandy loam, the difference being due to a slightly higher percentage of organic matter. The percentage of silica in the parent rock (disintegrated gneiss) is no lower than in the Cecil soils.

The percentage of clay in A_1 (A_2 was not analyzed) is 8.7 and of silt is 19.7. The sand present consists predominantly of fine sand, but 13 per cent of coarse sand and the same of very fine sand show the presence of sand of all sizes in relatively large proportions. Clay in B is 43 per cent but in the upper part of C_1, not shown in table, is only 6. The texture profile is well developed. The podzolic chemical profile is also well developed, though the percentages of sesquioxides in A_1 are higher than in Cecil sandy loam where well developed.

The percentage of potash is high, but higher in C than in the solum. That in A_1 is higher than that in B, however. The percentages of Na_2O and CaO are low in the solum, but that of Na_2O in C_2 is high. The percentages of alkalies and alkaline earths is high when compared with those in Cecil sandy loam.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 124.

Table 124.—*Porters loam, Chimney Rock, N. C.*

Sample No.	Horizon	Depth in Inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
35000	A_1	0–4	10.64	86.3	0.709	1.29	0.015	0.121	0.086
35001	B	14–48	4.87	32.5	.229	1.09	.033	.224	.052
35001B	C_2	96+	8.55	70.0	.910	1.19	.017	.140	.127

The sa ratio for C_2 is a little less than twice that for B, and the relative number of molecules of SiO_2 in B is 10 per cent less than the number in C_2, per unit of weight, indicating the presence of more alumina in B than can be accounted for by loss of silica from B. The sa ratio for horizon A is 25 per cent greater than that for C_2 and more than twice that for B while the relative number of molecules of silica in A is less than 10 per cent greater than in C_2 and 20 per cent greater than in B. The high ratio in A must be accounted for to a great extent through removal of alumina.

The sf ratio in B is less than 50 per cent of that in C_2, and that in A is more than two and one-half times that in B and a little more than 20 per cent greater than that in C_2. The difference in sf ratios between B and C_2 is greater than that in sa ratios, again suggesting the greater accumulation of iron oxide than of alumina in B. The alumina-iron oxide molecular ratios in B and C_2 are 6.7 and 8.1, respectively. Alkalies and alkaline earths have been lost throughout the solum. The relative number of molecules, per unit of weight, in B is a little less than half that in C_2, and the number in A is 50 per cent less than in C_2 but 60 per cent higher than in B.

This soil is essentially the equivalent of a moderately well developed Cecil sandy loam in all respects except the higher percentage of organic matter and of alkalies. The prevailing temperatures on the Blue Ridge plateau, standing 2,500 feet above sea level and somewhat more than 1,200 feet above the piedmont plateau in the same latitude, are lower than on the piedmont plateau, and the rainfall is as high or higher. The organic matter does not disappear so rapidly. These soils were originally differentiated from the Cecil on the basis of their occurrence on the plateau, in another physiographic region and another soil province, as soil provinces were then defined, rather than on the basis of soil character.

COMPOSITION OF DAVIDSON AND IREDELL SOILS

Davidson soils are Red soils, developed from dark-colored quartz-free rocks, usually diabase, basalt, or metamorphic rocks of similar mineralogical composition. Because of the heavy texture of their decomposition product the soils develop a podzolic, or eluviated, profile very slowly. These soils are associated with the Cecil and other Red soils of the piedmont plateau and have as a rule very slight profile development. The red color extends to the surface, but in most cases the color of the upper 2 or 3 inches is yellowish red, the rest of the profile being deeper red than the corresponding horizon in the Cecil soils.

The chemical and mechanical composition of material from a profile of Davidson clay loam, from Greensboro, N. C., published by Anderson and Byers (*1*) are shown in Table 125. The composition of colloid is shown in the same table *(d)*.

Table 125.—*Composition of Davidson clay loam, Greensboro, N. C.*[1]

Horizon	Depth	Chemical [2]														
		SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*
A	0–9	[a]70.53	1.80	6.10	12.45	0.22	0.75	0.45	0.58	0.00	0.10	0.12	7.66	100.76	0.110	------
		[b]76.38	1.95	6.61	13.48	.24	.81	.49	.63	.00	.11	.13	------	100.83	------	------
		[c]34.43	1.99	12.40	32.10	.24	.58	.92	.50	.03	.25	.17	17.08	99.69	------	------
		[d]41.52	1.19	14.95	38.71	.29	.70	1.11	.60	.03	.30	.20	------	99.60	------	------
B_1	9–36	[a]52.70	1.39	10.62	22.87	.07	.51	.40	.45	0	.12	.12	10.55	99.80	.020	------
		[b]58.92	1.55	11.87	25.57	.08	.57	.45	.50	0	.13	.13	------	100.47	------	------
		[c]36.92	.92	16.03	31.67	.06	.56	.41	.37	0	.18	.12	13.14	100.38	------	------
		[d]42.50	1.06	18.45	36.46	.06	.64	.47	.42	0	.20	.13	------	100.43	------	------
B_2	36–60	[a]50.53	1.47	14.87	23.05	.08	.27	.58	.34	0	.20	.12	9.37	100.88	.010	------
		[b]55.85	1.62	16.40	25.43	.09	.30	.64	.38	0	.22	.13	------	100.95	------	------
		[c]35.37	.98	20.61	29.44	.08	.35	.36	.18	Tr.	.17	.11	12.30	99.85	------	------
		[d]40.33	1.11	23.50	33.57	.09	.40	.41	.20	Tr.	.19	.12	------	99.93	------	------
C	60+	[a]52.62	1.23	13.37	20.98	.47	.27	1.00	.72	0	.24	.09	9.15	100.14	.010	------
		[b]57.92	1.36	14.71	23.09	.52	.30	1.10	.79	0	.26	.10	------	100.15	------	------
		[c]35.24	.95	20.10	29.69	.30	.50	.06	.17	Tr.	.36	.14	12.53	100.04	------	------
		[d]40.29	1.08	22.98	33.94	.34	.57	.06	.19	Tr.	.41	.16	------	100.32	------	------

Horizon	Depth	Mechanical [3]							
		Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
	Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Percent*
A	0–9	0.7	2.3	2.6	9.6	16.7	29.4	34.3	95.6
B_1	9–36	.1	.7	.9	5.4	8.9	22.3	60.4	98.7
B_2	36–60	.3	1.0	.9	7.2	9.1	30.4	50.3	99.2
C	60+	.4	1.3	1.9	14.3	17.5	34.5	29.6	99.5

[1] Collected by H. G. Byers and R. C. Jurney.
[2] Analyzed by G. J. Hough.
[3] Analyzed by L. T Alexander and H. W. Lakin.

This soil is described by Anderson and Byers (*1*) as Lateritic, the assignment to this group of soils being based on the low silica-sesquioxide ratio, showing extensive removal of silica. The exact composition of the rock from which the soil material was accumulated by residual decay has not been determined. It is a diabase, and on the basis of the composition of diabases generally it may be safely stated that the silica-sesquioxide ratio in the rock can not be much less than 4. The sa ratio of the colloid in horizon B_1 is 1.98. The silica-sesquioxide ratio of the colloid ranges between 1.40 and 1.50. Defining Lateritic soils as those in which this ratio is less than 2 gives the authority for such an assignment in this case. There is no universal agreement among students of tropical soils as to whether a low silica-sesquioxide ratio should be used as the criterion or a low silica-alumina (sa) ratio. The latter ratio has been used in preceding pages of this report. Harrassowitz uses the latter without defense, or without the consideration of any other, and if that be used it is seen that the ratio is almost exactly that of kaolin.

The dark-colored rocks, such as diabase and basalt, contain high percentages of augite, with more or less hornblende and biotite. Augite contains a very low percentage of alumina, the molecular silica-alumina ratio in most places being higher than 10. If that were the only mineral present the proportional loss of silica required to reduce the ratio to 2 or below would be much greater than in the light-colored rocks. The feldspathic mineral associated with these dark-colored minerals in diabase or basalt anorthite has a very high percentage of alumina and a relatively low percentage of silica. The silica-alumina molecular ratio, therefore, in the mineral is almost exactly 2. The silica-alumina ratio of the rock, therefore, is almost the same as that of granite.

In the decomposition of such a rock, however, the dark-colored minerals decompose very rapidly. This is a fact of observation known to every geologist. The silicate silica disappears at a rapid rate as compared with that in a more slowly decomposing granite.

The anorthite or other basic feldspar in diabase or basalt would probably decompose more rapidly than the orthoclase of granite, but very little decomposition of the anorthite would be necessary to bring the silica-alumina ratio of the decomposed product below 2. The silica-alumina ratio of the decomposition product of the augite, although the amount of silica that must be lost would be large, would soon reach 2 or less because of the rapid rate of decomposition of this mineral.

As a whole, therefore, the dark-colored rocks will attain the lateritic or allitic stage of decomposition earlier than will associated light-colored rocks, and conversely the former rocks will decompose into an allitic or lateritic product in a higher latitude than will the latter rocks. Although the Davidson soils seem to have reached the lateritic stage of weathering it does not follow that the soils of the region in which they occur have attained the same stage.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, Al_2O_3 and the sum of the molecular equivalents of the alkalies and alkaline earths, except magnesia, are shown in Table 126, and the same for the colloid from the same soil are shown in Table 127.

Table 126.—*Davidson clay loam, Greensboro, N. C.*

Horizon	Depth in inches	Ratios			Molecular equivalent composition			
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
A	0–9	9.28	29.50	0.1600	1.225	0.041	0.132	0.0212
B_1	9–36	3.92	13.15	.0618	.981	.074	.250	.0155
B_2	36–60	3.73	9.00	.0371	.928	.102	.249	.0094
C	60+	4.26	10.45	.0607	.965	.092	.226	.0137

TABLE 127.—*Colloid of Davidson clay loam, Greensboro, N. C.*

Horizon	Depth in inches	Ratios			Molecular equivalent composition			
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
A	0–9	1.82	7.36	0.057	0.688	0.093	0.379	0.0194
B_1	9–36	1.98	6.10	.044	.705	.115	.357	.0159
B_2	36–60	2.04	4.54	.028	.669	.147	.329	.0093
C	60+	2.02	4.76	.036	.666	.143	.332	.0122

The high sa ratio for A compared with the same ratio for B_1, B_2, and C tends to exaggerate the importance of silica. This is the case, however, only when sa is used as the basis of determining the relations of either silica alone or alumina alone in the three horizons. The molecular equivalent composition shows that silica, per unit of weight, is only about 30 per cent higher in A than in C. The relative number of iron oxide molecules per unit of weight is lower in B_1 and A than in C. Iron oxide has been removed from A but has not accumulated in B_1. There is a slight accumulation in B_2.

The increased number of molecules of alumina in B_1, per unit of weight, over those in C amounts to a little less than 10 per cent of those in C, whereas those in A are 40 per cent less than in C.

The increase in the number of molecules of alkalies and alkaline earths in B_1 over those in C and in A over those in B_1 is unusual among the Red soils if among no others. The increase in B_1 over those in C is a little more than 10 per cent, and the number in A is more than 50 per cent greater than in C.

The sa ratios in the colloid of the several horizons show somewhat more leaching of silica from the A and B_1 horizons than from C. The molecular equivalent composition in SiO_2 and Al_2O_3 in the colloid is relatively uniform throughout the profile. The percentage of iron oxide is lower in the colloid of the upper horizons than in that of the lower.

The Davidson soils are well oxidized and have begun to develop a profile. They are associated with the soils of another series, the Iredell, which have developed from the same kind of rocks. The Iredell soils are less deeply weathered, however, than the Davidson.

The chemical and mechanical composition of material from a profile of Iredell loam from West Bend, Iredell County, N. C., are shown in Table 128.

TABLE 128.—*Composition of Iredell loam, West Bend, Iredell County, N. C.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
236921	A	0–5	[a] 63.32	1.29	12.49	9.30	0.36	3.11	4.75	0.13	0.31	0.04	0.05	5.25	100.40	0.043	------
			[b] 66.78	1.36	13.17	9.81	.38	3.28	5.10	.14	.33	.04	.05	------	100.44	------	------
236922	B	5–25	[a] 45.79	.61	10.93	24.70	.12	1.97	3.96	.11	1.16	(3)	.05	11.00	100.40	.046	------
			[b] 51.43	.69	12.28	27.74	.14	2.21	4.45	.12	1.30	(3)	.06	------	100.42	------	------
236923	C	25+	[a] 44.30	.39	10.25	19.27	.18	7.62	12.21	.20	.64	(3)	.03	5.02	100.11	.011	------
			[b] 46.64	.41	10.79	20.28	.19	8.02	12.86	.21	.67	(3)	.03	------	100.09	------	------

Sample No.	Horizon	Depth	Mechanical [4] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
236921	A	0–5	10.7	10.8	4.0	27.0	22.4	18.1	6.9	99.9
236922	B	5–25	.5	1.7	1.8	15.7	11.4	18.2	50.4	99.7
236923	C	25+	.6	3.8	4.4	45.3	23.3	16.2	6.4	100.0

[1] Collected by W. D. Lee.
[2] Analyzed by G. Edgington.
[3] Trace.
[4] Analyzed by J. B. Spencer.

The percentage of alumina is lower in the upper 5 inches than below that depth. The character of the parent rock is brought out in the very low percentage of potash and the high percentage of calcium. The percentage of Na_2O also is relatively low. The percentage of clay in the thin 5-inch A horizon is 7 and that of silt is 18. The sand present is dominantly fine and very fine, with 11 per cent of coarse sand. In horizon B the percentage of clay is 50.4, but that of silt remains 18, the rest of the material being fine and very fine sand. Clay in C amounts to 6.4 per cent only, this horizon consisting of disintegrated diabase only. Fine and very fine sand are dominant, amounting to 68.6 per cent.

The percentage of iron oxide is high and almost uniform throughout the profile. That of alumina is moderate for the profile as a whole but is relatively low in A and high in C. Magnesia and CaO are very high, the former more so than the latter.

The ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, Al_2O_3, and the sum of the molecular equivalents of alkalies and alkaline earths, except magnesia, are shown in Table 129.

TABLE 129.—*Iredell loam, West Bend, Iredell County, N. C.*

Sample No.	Horizon	Depth in inches	Ratios			Molecular equivalent composition			
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
236921	A	0–5	11.57	13.43	0.680	1.107	0.082	0.096	0.0654
236922	B	5–25	3.15	11.10	.223	.850	.077	.271	.0622
236923	C	25+	3.91	11.78	.787	.773	.067	.198	.1560

The complete analysis and the sa ratios show that an A horizon has developed. The removal of material from the A has consisted of the alumina and CaO, the iron oxide not having been removed. The amount of the latter, relative to silica, is a little less in A than in B, but the molecular equivalent composition shows a higher number of molecules per unit of weight in A than in B and a higher number in the latter than in C.

The high percentage of lime is probably responsible. The combined alkalies and alkaline earths relative to alumina, are high in A, low in B, and high in C, the percentage in A being only about 14 per cent lower than in C, but that in B is less than a third of that in C. The molecular equivalent composition shows that the number of molecules of alkalies and alkaline earths per unit of weight in A and B is almost equal, but it is less than half that in C. In all three horizons it is high. Some accumulation of alumina in B has taken place, the number of molecules per unit of weight in B being about 37 per cent greater than in C, but that in A is only half that in C.

The chemical and mechanical composition of material from an Iredell profile from Guilford County, N. C., together with that of colloid from a very faintly developed B horizon (10 to 20 inches) are shown in Table 130. High CaO, iron oxide, and magnesia are characteristic of young soils developed from ferromagnesian rocks. The A horizon has lost some alumina but very little iron oxide and alkalies or alkaline earths. The sand in A contains other minerals than quartz, and the development of A has taken place through the removal of very fine particles from the soil rather than by eluviation. The silica-sesquioxide ratio in the colloid of the B horizon is 1.88, and the silica-alumina ratio is 2.57.

TABLE 130.—*Composition of Iredell loam, Greensboro, Guilford County, N. C.*[1]

Horizon	Depth	Chemical [2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A_1	0–5	[a] 56.40	2.41	12.34	11.17	0.270	4.43	0.92	0.20	1.48	0.31	0.18	10.50	100.61	0.270	------
		[b] 63.01	2.69	13.78	12.48	.300	4.95	1.02	.22	1.54	.34	.20	------	100.53	------	------
A_2	5–10	[a] 60.56	2.38	12.37	11.83	.220	4.38	.94	.20	1.79	.21	.13	5.03	100.04	.030	------
		[b] 63.77	2.50	13.02	12.45	.230	4.60	.99	.21	1.88	.22	.14	------	100.01	------	------
B	10–20	[a] 47.70	1.84	13.82	21.52	.050	2.92	1.25	.21	1.19	.15	.08	10.00	100.73	.040	------
		[b] 53.00	2.04	15.35	23.91	.050	3.24	1.39	.23	1.32	.17	.09	------	100.79	------	------
		[c] 40.73	1.91	15.45	26.94	.014	.97	.93	.11	0	.13	.16	12.44	99.78	.150	------
		[d] 46.51	2.18	17.64	30.76	.019	1.11	1.06	.12	0	.15	.18	------	99.72	------	------
C	20–27	[a] 47.52	1.82	12.85	20.22	.180	5.77	2.45	.26	2.00	.20	.09	6.96	100.32	.020	------
		[b] 51.07	1.95	13.80	21.73	.190	6.21	2.63	.28	2.15	.22	.10	------	100.33	------	------

Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
	Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
A_1	0–5	4.3	6.0	4.5	11.7	13.2	42.2	18.0	99.9
A_2	5–10	5.5	4.7	3.3	10.9	13.1	45.9	16.5	99.9
B	10–20	.6	.9	1.0	3.5	5.3	24.4	64.2	99.9
C	20–27	1.0	3.7	4.7	13.4	12.5	28.9	35.7	99.9

[1] Collected by H. G. Byers and R. C. Jurney.
[2] Analyzed by G. J. Hough.
[3] Analyzed by L. T. Alexander.

THE PRAIRIE SOILS

The soils of the prairies of the United States have been separated into a group comparable to the Gray-Brown Podzolic and the other great soil groups. Whether finally these soils will be recognized as a soil group comparable to the Gray-Brown Podzolic soils is not yet known. The soils are so entirely different from those of any of the other great groups that, for the present, it seems very unwise to attempt to include them in any of the established groups. The area shown on plate 2, and the area in which Prairie soils are shown on the large soil map is defined not on the basis of the occurrence of grassland but entirely on the basis of the character of the soils. While this coincides, on the north, east, and south, with the grassland boundary, on the west grassland extends far beyond what is recognized here as the Prairie boundary. The Prairie soils are grassland soils, but were developed under a high rainfall. In this respect they seem to be unique, not occurring elsewhere in the world, except possibly in small areas, and where they do occur, have heretofore been designated as degraded Chernozems.

East of the general eastern boundary of the Prairie soils, small areas of soils similar to those of the prairies occur, which also were developed under grass cover. These areas are scattered, here and there, through Michigan, Indiana, and Ohio, and apparently also in Kentucky. In detailed mapping they have been differentiated from the normal soils of the Gray-Brown Podzolic group surrounding them. They are all degraded and are approaching in character the normal Podzolic soils surrounding them. On the large map in this publication, they are not shown separately because of the small area covered by each of them.

Plate 2, shows the general distribution of the soils included in this group. Like the other areas on this map, it shows the boundaries of the region throughout which well-developed soils having the characteristics of the soils of the group occupy important areas though they are not necessarily dominant. Within the area designated as that of the Prairie soils a rather large proportional part is occupied by soils whose characteristics are different from those of the typical members of the group. It is probable that the proportion of such soils is greater in the prairie region than in that of any other group. This is because the fundamental characteristics of the typical Prairie soils are entirely different from those of any of the groups described on the preceding pages.

Typical Prairie soils are not Podzolic, but soils of all the groups previously discussed are Podzolic. Although development seems to have taken place under the influence of a rainfall high enough to have podzolized them, Prairie soils do not have the Podzolic profile. A possible reason for this will be given later. We are concerned here with the mere fact that the surface horizon of the somewhat theoretically typical Prairie soil has not been leached of its bases to such an extent as to make it acid in reaction, to deflocculate its colloids, or to produce an eluviated horizon.

The typical Prairie soil profile has a very dark brown or black surface horizon, or layer, the blackness being caused by the presence of a high percentage of organic matter. The structure is granular with rather fine grains. This layer is underlain by a brown horizon which is little if any heavier in texture than the surface horizon but differs from the surface layer in the much lower percentage of organic matter and in the brown color. The material in this layer usually falls, on exposure, into rather large roundish grains in the upper part and in the lower part into angular particles ranging up to about half an inch in diameter, larger than the granules in the upper part. This layer, in turn, is underlain by parent material ranging widely in character.

The profile just described is the ideal and somewhat theoretical profile. The soil over most of the area is less dark than the typical soil, is slightly acid at the surface, the colloids in the surface are slightly deflocculated, and very slight eluviation has taken place. The soil is in the earliest stages of podzolic development. In

soil survey work a soil in the prairies is accepted as a member of the prairie group if the surface horizon has a well-defined dark color and is 8 or more inches thick. Most of the Prairie soils are slightly degraded.

Considerable areas of Gray-Brown Podzolic soils occur in the northern part and of Red and Yellow soils in the southern part of the prairie region. So far as is now known the Prairie soils are the original soils within this region, whereas the Gray-Brown Podzolic soils within the same region have been developed in recent geological time in areas where original Prairie soils either have been changed, or new soil has been developed in places where Prairie soils have been removed by erosion, the new soils not being Prairie soils. Prairie soils occupy the smooth uplands which have not yet been thoroughly dissected, while the streams within the area are bordered by belts, varying in width approximately according to the size of the streams, in which Gray-Brown Podzolic soils occur.

It is generally considered by botanists that the prairie region is potentially a forest region. By that is meant that this region would have been occupied by forest, except for what may be considered an accident. The persistence of grass vegetation through a long period of time is considered to be the result of an accident and is not an expression of the natural environment of the region.

The light-colored Gray-Brown Podzolic soils lying within the belts along the streams of the region are soils which have a more complete adjustment to the climatic conditions of the region than the Prairie soils. Since, however, the climate is only one of the dynamic factors which develop soils, natural vegetation being another and apparently a very strong one, and since the character of the Prairie soils seems to have been determined by the grass vegetation, it is apparent that the Prairie soils may be considered not as soils without normal development, but as an expression of the operation of both the dynamic factors of soil development, to the action of which all soils are subject, but in which the particular combination of forces has been somewhat unusual. They are the product of an association of natural grassland with a humid climate. The usual association is with a semiarid climate. In this case the natural vegetation has, up to the present time, overcome the normal effect of the climate. It has proved to be, so far, the stronger factor.

In the forested areas along the streams where Gray-Brown Podzolic soils have developed, the two dynamic factors have operated in harmony to produce the Gray-Brown Podzolic soils, or if not in harmony, the influence of the prevailing forest vegetation has been relatively less effective than the grass vegetation in the Prairie soils.

Since the grass in this region is not what botanists call a climax vegetation, its presence must be described as accidental. It is not necessary to discuss the reason for this, as it is an ecological matter.

In general the Prairie soils may be subdivided into nine subgroups. These may be designated as the Carrington, Clarion, Marshall, Summit, Cherokee, Crete, Houston, Webster, and Lake Charles subgroups. These subgroups are designated by the name of the dominant soil series in each, and each predominates in a given part of the prairies.

CARRINGTON AND ASSOCIATED SOILS

This group includes the soils of the Carrington, Shelby, and a few less important series. These soils are very important well-drained soils of the northern prairies. They are the dominant soils in southeastern Minnesota, eastern Iowa, northern Missouri, and part of southeastern Nebraska, and they occur in important areas in Northern Illinois. (Pl. 5, secs. 2, 6, and 7.)

The soils of the Carrington series are probably more nearly normal in all respects than are those of other members of the group. They have developed from glacial drift, predominantly slightly calcareous, on rolling relief with the ground water surface well below the bottom of the solum.

The profile is characterized by a dark-brown surface soil, rarely becoming black, in which the dark-colored layer extends to a depth of about a foot except where erosion from, or accumulation on, the natural surface has taken place. This layer constitutes an ill-defined A horizon. It is underlain by a brown, slightly heavier B horizon, the transition from A to B being gradual. Except in the sandy members, the material of the B horizon breaks naturally into rather well defined angular structure particles about one-fourth or one-half inch in diameter. In the normal soil the color is essentially uniform on a broken or evenly cut surface, the former being darker than the latter because of a more or less dark-colored coating on the outsides of the particles which are usually free from gray coating. This horizon extends to a depth of about 3 feet and is underlain by parent glacial drift leached of its carbonates and somewhat oxidized to a depth ranging up to 10 feet, depending on the texture and on the percentage of carbonate in the unweathered material.

Where the Carrington soils lie on smooth surfaces some eluviation has taken place. This is merely an expression of the slight acidity of these soils. They vary somewhat in this respect, ranging, as they have been mapped, from Carrington soils with a B horizon simulating that of the Gray-Brown Podzolic soils, with maximum acidity in the A horizon and a comparatively light color, to soils entirely free from eluviation and with a black surface color. The B horizon of the Carrington soils is usually slightly acid and is immediately underlain by material that does not effervesce in acid. Downward, however, it is calcareous below the level to which leaching has extended.

As shown on the large soil map the Carrington soils, especially in eastern Iowa, include a considerable area of silty soil developed from material that is usually identified as loess. The profile, however, of this soil, which is mapped in detailed mapping as Tama silt loam, is essentially identical with that of the silt loam of the Carrington series. The silty material beneath the B horizon of the Tama soils is not calcareous above a depth of 6 feet.

In the main area of occurrence of the Carrington soils, especially in eastern Iowa and central Illinois, these soils are associated with imperfectly drained soils which have been mapped as members of the Grundy series. The latter are not so imperfectly drained as the Clyde or Webster soils, the imperfect drainage manifesting itself only in the B horizon. They are darker in color, however, than the associated Carrington soils, since their occurrence on flat or even slightly depressed areas gives them a higher water content than is usually present in the Carrington soils, and the grass cover is more luxuriant. They are also somewhat less leached in the A horizon than the Carrington soils. The A horizon is underlain by a horizon mottled in rather a characteristic way. It breaks into a great number of small subround particles. The color on the outside of each particle is dark, whereas inside each particle is a band first of gray, succeeded by yellowish, and finally by rust-brown material, the latter occupying the center of the particle. The particles range around a quarter of an inch in diameter. Downward the particles become larger and the dark-colored coating less and less marked, finally disappearing at a depth of 3 or 4 feet, below which lies the glacial drift of the region, thoroughly leached and weathered to a depth of several feet. Effervescence in acid does not take place above a depth of 5 feet.

Shelby soils cover an important area in south-central Iowa, northern Missouri, and northeastern Kansas. They occur also in Nebraska but in the latter State have been shown on the map as Carrington because of the small areas in which they occur. In their essential fundamental characteristics they are Carrington soils. They have been differentiated from the Carrington in detailed mapping largely on a theoretical basis, having been derived from an older glacial drift than that from which most of the Carrington soils have developed. They occur also on more rolling relief, have been subjected to better drainage and more complete oxidation, the soil minerals are more completely decomposed, and the B horizon is slightly reddish and heavy, the heavy texture being partly due to eluviation. They have become slightly acid in reaction, partly because, occurring on rolling relief, the grass cover was not so luxuriant as on the smooth uplands where the associated soils developed. The less luxuriant grass cover was due to the smaller water supply, a larger proportion of the natural rainfall having been lost in run-off than on the smooth uplands. For this reason, therefore, the Shelby soils as a rule contain a somewhat lower percentage of organic matter, and the dark-colored layer is thinner than in the Carrington soils. Because of development from older drift, they have been more thoroughly eluviated and the reaction has become slightly more acid. The profile has characteristics aligning it with both the Prairie and the Gray-Brown Podzolic soils.

CLARION AND ASSOCIATED SOILS

The Clarion soils cover the northern part of the prairie region, occurring in Minnesota, northern Iowa, and northern Illinois. Of the Prairie soils developing under good drainage and in a normal direction, without interference by local conditions, these are the youngest. Their profile has developed to a depth of about 2½ feet, so that it may be considered almost mature. The surface soil is dark-brown or black granular material, usually sandy loam or heavier, and it ranges from 10 to 15 inches in thickness. On account of prairie fires it is rarely found with a layer of decaying vegetable matter overlying the mineral soil. It is apparent that this condition has persisted throughout the period of the development, not only of this but of all the Prairie soils. These soils differ from the Gray-Brown Podzolic soils in this respect as well as in others. The dark color of these soils is owing to material accumulated within, and not on, the soil. Whatever effect on the color of the upper part of the mineral soil within the forested region may have been brought about by the action of insects and worms, it is apparent that, although they have undoubtedly operated within the prairie region, they have had a comparatively unimportant effect in increasing the darkness of the color of the upper part of the prairie soils. It is probable, however, that they have, in some cases at least, increased its thickness by carrying material downward, but the additional thickness due to the action of organisms other than vegetative, seems to have been small.

The reaction of the surface soil of the Clarion soils is generally neutral. The organic and mineral colloids are saturated, and the structure, except where the material is light in texture, such as sandy loam, is granular. The dark-colored layer may be designated as the A horizon, but it is not an A horizon similar to the A horizon of the Gray-Brown Podzolic soils. The texture of the A horizon of the Prairie soils has not been changed significantly by eluviation. The mechanical analyses of a sample of Prairie soil, Marshall silt loam, shown in Table 136, made of the material after the organic matter had been removed by treatment with hydrogen peroxide, show that the A horizon is very slightly lighter in texture than the B.

The B horizon is brown. The material may or may not break into angular particles similar to the B horizon of the Gray-Brown Podzolic soils, but it is little or no heavier than the A horizon. Where it breaks into particles, angular or otherwise, the organic matter has been carried downward along the cracks between the soil particles, giving them a dark-colored coating. It is apparent that the thickness of the dark-colored layer has been increased downward to a greater extent by the action of water than by the action of insects. Neither the A nor the B horizon contains free lime carbonate in sufficient quantities to effervesce in acid. They are both practically neutral in reaction, however. Immediately beneath the B horizon, at a depth ranging from 2½ to 3 feet, lies the parent material consisting of highly calcareous glacial drift. This material is identical in its general characteristics with that underlying the Miami soils, but the Clarion soils are widely different from the Miami. Their difference, however, is a soil difference rather than a difference in the character of the parent material, which consists in both cases of glacial drift of late Wisconsin age. The soils, therefore, from the point of view of the time during which they have been developing, are young soils. They are not, however, necessarily the youngest soils in the region. They occur in association, for example, with Webster soils, which are younger than the Clarion because they are less well developed as soils. The Webster soils have developed in depressed situations where they have been subjected to the influence of excessive moisture. They bear the same relation to the Clarion soils as the Clyde bears to the Miami. They are black soils, with bluish or bluish-gray subsoils. The surface soil may or may not contain enough free carbonate to effervesce in acid, but effervescence occurs a short distance below the surface.

The Brookston and Clyde soils, theoretically at least, will develop into Miami soils in the future when they have been subjected to normal development under good drainage for a long time, but the Webster soils will not develop into light-colored soils, at least until after they have passed through a stage similar to that of the Clarion. After the Clarion soils finally pass through the stage of their existence marked by the presence of Prairie soil characteristics, which seem to be temporary, and change to Gray-Brown Podzolic soils, presumably the Webster soils will change also.

MARSHALL SILT LOAM

Along the Missouri River in western Iowa, eastern Nebraska, northeastern Kansas, and northwestern Missouri (fig. 34), is a rather broad belt covered by Marshall soils in which the dominant soil is Marshall silt loam. In general profile features this soil is similar to the Carrington, but the reaction of the typical Marshall is neu-

tral. Southward along the river the reaction becomes acid, very slightly at first. In the extreme southern part of the area of its occurrence, in western Missouri, it is more acid than farther north and the profile therefore has become somewhat eluviated. This is also true of the soils in northeastern Kansas, but northward in western Iowa and northeastern Nebraska the profile is essentially like that of the Clarion soils so far as eluviation is concerned. The dark-colored A horizon is about as thick or a little thicker than that of the Clarion soils, and the structure is granular. The percentage of organic matter is slightly less than that in the Clarion soils and the color is a little less intensely black. The B horizon is brown silt loam which may or may not be slightly heavier than the A horizon but is usually heavier in the southern part of the belt. Neither the A nor the B horizon, however, contains sufficient calcium carbonate to effervesce in acid. Beneath the B horizon is loose yellowish silty material which may contain iron spots, especially in the southern part of the belt, and which effervesces in acid at a depth ranging from only a few inches below the B horizon in the northern part of the belt to several feet in the southern part.

The soils of the northern end of the Marshall belt and the uneluviated soils of the Carrington and Clarion series are considered typical soils of the prairie region. They seem to be characterized by features constituting the fullest expression of the conditions under which they developed. These features have been modified very little by what may be designated degradation processes. The typical Marshall and Clarion soils have not yet been degraded, and those of the Carrington series are only slightly so. The colloids are still saturated with bases, the organic matter is not yet being dissolved rapidly, and eluviation has not taken place. Most of the Prairie soils, however, have been slightly, and some of them strongly, degraded. This is to be expected because of their development under the influence of a heavy rainfall. As long as the grass vegetation is able to overcome the leaching effect of the large amount of percolating water to an extent sufficient to maintain the colloids in the surface soil in a saturated condition, they will not be degraded. Theoretically, a stage will be reached in the development of all Prairie soils where the grass will be unable to maintain this condition. The discussion of the attainment of this stage can not be taken up here, but it is apparent that this stage has been attained in a great many of the Prairie soils, among them being the Marshall soils in the southern part of the Marshall belt, and in a considerable part of the Carrington soils. The Clarion soils have not yet reached this stage of development.

SUMMIT AND ASSOCIATED SOILS

A large area of Summit soils is shown on the map in eastern Kansas and western Missouri south of Missouri River. These soils have developed from material accumulated by the decay of the country rock rather than from glacial material, this rock consisting of shales, sandstones, and limestones. The shales underlying the true Summit soils are predominantly slightly calcareous. The soils are normal silt loams or heavier. The Summit soils constitute the normally developed Prairie soils of this region, but the area shown on the map as Summit contains considerable areas of soils which are not typically Summit soils. The true Summit soils, as these soils are now defined in the detailed work of the Soil Survey, probably occupy a minor part of this total area. Since, however, they represent the normal or most nearly normal soils of this region, the whole area has been shown as Summit. Being Prairie soils they are dark and have a neutral or very slightly acid reaction in the surface soil. The structure is granular, usually rather well defined, and the thickness of the dark-colored layer ranges up to about 12 inches. It is underlain by a B horizon somewhat heavier than the A (since these soils have been slightly eluviated) which breaks into angular particles of subround granules ranging up to a quarter of an inch in diameter. The granules are coated dark in color on the outside by organic matter, and they are brown on the inside. Downward the organic matter decreases and disappears at a depth ranging from 3 to 5 feet, below which lie the clays resulting from the disintegration of the country rock.

FIGURE 34.—Grassland with trees on degraded Marshall silt loam, Andrew County, Mo.

The Summit soils are associated with the Crawford soils which occur in small areas in the eastern part of the Summit region and in larger areas in the western part and in Texas. The Crawford soils differ from the Summit by having developed from material accumulated by the decomposition of limestones and calcareous shales. The surface soils are dark, being similar to the Summit soils in this respect, but the B horizon is reddish, having been derived from limestone material, this being especially true in Texas and southern Kansas. The B horizon is underlain at slight depths, ranging from 2 to 5 feet, by limestones.

Bates soils also are associated with the Summit soils and differ partly in their derivation from noncalcareous shales. They differ also in the thinner layer of disintegrated and decomposed material from which they have developed. This layer is rarely 2 feet thick, so that the soil profile is incompletely developed. The color of the A horizon is not so dark as that of the Summit soils since podzolization has already begun. The absence of lime carbonate in the parent material has prevented the maintenance of a saturated condition of the organic matter in the surface soils, so that they have become more thoroughly podzolized or more thoroughly degraded than the Summit soils.

The soils of a rather large area in Texas have been mapped as members of the Windthorst series. In all essential respects they may be considered as members of the Bates series, but as a whole they are somewhat lighter in color and the layer of disintegrated material overlying the rock is thicker. They have developed under grass cover, but the density of the grass cover is not very great and an open growth of oaks has spread over at least part of the region. A large part of the area mapped as Windthorst is underlain by imperfectly developed soils due to the activity of erosion. The Windthorst soils are associated also with soils occupying a considerable area and mapped as members of the Denton series which are similar in their general characteristics and also in the source of their parent material to the Crawford. They are somewhat more shallow than the Crawford soils, and the B horizon is grayish or yellowish rather than red. The reason for this is that these soils have been derived from calcareous shales to a greater extent than from limestones, and reddish soils do not develop from such materials as readily as from limestones. It will be recalled that in the discussion of the Decatur soils in the southern Appalachian region (p. 46), attention was called to the fact that red or reddish soils are associated with limestones high in carbonates rather than with calcareous shales.

SOILS WITHOUT NORMAL PROFILES

The Prairie soils so far described have either what are regarded as typical prairie profiles or are soils in which the profiles have been somewhat modified by degradation or podzolization. Throughout the prairie region, however, there are large areas covered by soils which have not now a normal profile and presumably never had, and the existing profile is not the product of degradation or of podzolization of a Prairie soil profile. In some cases ground water has been a factor; in other cases the character of the parent material seems to have been a factor. These soils may be designated as a whole as soils without normal profiles. Since they have developed, however, under natural conditions it is not strictly correct to describe their profiles as not normal but at least they are not profiles which have developed under an unimpeded and free action of the two dynamic soil-developing factors of the region—natural vegetation and climate. The characteristics of their profiles are due to the operation of these two factors modified by others which have changed the normal course of profile development.

The unusual feature in the profiles of these soils, which differentiates them from the normal Prairie, the degraded Prairie, or the Gray-Brown Podzolic soils, consists of a B horizon of heavy tough plastic clay very similar in its characteristics to the heavy horizon of the Solonetz soils.

CORY, PUTNAM, AND ASSOCIATED SOILS

The Cory soils occupy a large area in south-central Illinois, south of the region of Carrington soils. They have developed from old glacial drift and on flat relief where drainage has been imperfect. The surface drainage has not been sufficient to cause soil development similar to that which produced the Clyde, Brookston, and Webster soils where the water table has stood on the surface or above it during the period of soil development, but they have been exposed to excessive moisture during the winter and spring and to low ground water and, to a great extent, to excessive dryness in late summer and autumn. They have developed under a rather sparse grass cover. They do not have a dense black color in the surface soil but are merely dark brown. The dark-colored A horizon is predominantly silty and ranges up to 6 or 8 inches in thickness. The structure is only very faintly granular, and in many cases granulation can not be detected. The material has a horizontal or parallel arrangement, splitting into horizontal plates similar to those in the A horizon of the Gray-Brown Podzolic soils. The dark-colored layer is usually underlain by a grayish silty layer and this, in turn, by heavy tough plastic intractable clay which varies in color somewhat but is usually dark, especially on the outsides of the structure particles into which the material breaks. The heavy layer is underlain by silty clay material presumably derived from the decomposition of the underlying drift, but effervescence does not occur to a depth ranging from 6 to 10 feet.

A series of soils similar to those of the Cory series, occurs in flat areas in the western part of Illinois and in large areas of northeastern Missouri. It has been designated in detailed work as the Putnam series. The Putnam soils are somewhat darker and have a thinner gray layer between the dark-colored surface layer and the heavy clay beneath than the Cory soils. The heavy clay in the B horizon of the Putnam may be somewhat more extremely developed than in the Cory, but it breaks readily on drying into angular and blocky particles which furnish drainage, especially during a short rainy period following dry weather. After these particles, however, have become thoroughly wet and have expanded, the rapid downward percolation of water is stopped in both the Putnam and Cory soils, so that in periods of extended wet weather they become very much water-logged. The Putnam soils have developed from old glacial drift from which the lime carbonate has been removed to a great depth. This drift seems originally to have been largely calcareous. Both the Cory and Putnam soils are acid in reaction.

A similar soil, associated with the Grundy soils in southeastern Iowa, has been mapped as Edina silt loam. It is not shown on the map because of its occurrence in narrow belts along flat ridge tops. The Grundy soils, as heretofore described in association with the Carrington, occur in areas where the relief is a little more undulating than that in which the Edina soils occur.

In north-central Missouri and adjacent parts of Iowa, another series of soils, similar to the Putnam, has been mapped as the Grundy series. It is now known that these soils are not typical of the Grundy series and in future mapping will be given independent status. These soils differ from the Putnam soils in the darker color and great thickness of the surface soil, or A horizon, in the less perfect development of the gray horizon lying beneath the dark-colored horizon, and in less extreme development of the tough heavy clay horizon. In other words, these soils have not yet developed those characteristics peculiar to the Cory and Putnam soils to such an extreme extent as have the latter two soils. They are more nearly normal soils than the Putnam and Cory and lie, in soil characteristics, between these latter and the Carrington soils. They are more nearly related, however, to the Putnam soils than to the Carrington, since the clay layer is rather well developed.

CHEROKEE AND ASSOCIATED SOILS

In southwestern Missouri and southeastern Kansas, soils occupying a belt of considerable extent have been mapped as members of the Cherokee series. They have developed from material accumulated by the disintegration and decomposition in place of shales and sandstones. They are similar in general profile characteristics to soils of the Putnam series but differ in the color of the surface soil. They have de-

veloped under grass cover but have not developed the dark color characteristic of normal Prairie soils, or if such dark color was ever present it has been lost. They are now brown or dark brown to a depth of 6 inches and have a moderately well developed gray horizon beneath the dark-colored layer, the two constituting the A horizon. The B horizon ranges from moderately heavy to very heavy. It is less heavy apparently on the east side of the belt than on the west side.

In southeastern Kansas these soils attain their greatest extreme of profile development, the heavy layer being fully as heavy as that of the Putnam soils. In this region they differ from the Putnam soils only in the lighter color of the surface horizon and in parent material. They extend southward into Oklahoma and apparently entirely across that State into Texas. Since very little soil survey work has been done in Oklahoma, it is not known how extensively these soils occur. In profile characteristics, other than color of the surface horizon, these soils are similar to the Lufkin soils in Texas. It is known that a large proportion of the soils in eastern Oklahoma, where they have developed on smooth uplands, have a profile similar to that of the Cherokee soils.

Another group of soils associated with the Cherokee in southeastern Kansas, with a profile somewhat similar but less extremely developed, constitutes the Parsons series. The Parsons soils differ from the Cherokee in having a darker colored surface horizon, with a less well defined gray layer in the lower part of the A horizon. The B horizon is less extremely developed, and is not so heavy, hard, or intractable as the B horizon of the best developed Cherokee soils. The soils of both series are derived from the same material, this having been accumulated by the decay of shales in place. The Cherokee soils lie on areas of flat relief, and the Parsons soils lie on gently rolling areas.

It has been stated that the area shown on the map as that in which Summit soils are present contains probably less than 50 per cent of Summit soils. Some of the soils associated with the Summit are Parsons, together with small areas of Cherokee and Crawford soils.

The soil map (pl. 5, secs. 6 and 7) shows a rather large area of Kirkland soils in eastern Oklahoma. It is not known whether or not these soils are true Kirkland, but it is known that the soils of this region have a heavy clay horizon beneath the surface soil. The Kirkland soils are members of the same general group as the Parsons and Cherokee soils and differ mainly in the character of the parent material. They have been derived from calcareous shales, but it is apparent that in an important part of the area shown on the map the parent shales are not calcareous. In such cases they do not differ in any essential respect from the Parsons soils, where the color is dark, or from the Cherokee, where it is lighter. The subsoils are reddish in color. These soils are associated with the Vernon soils, especially in the western part of the area, the latter being younger soils not yet having developed a profile, the soil consisting of little else than red and reddish sandy clay. The color of the material is the color of the parent rock and is not a soil color. The true Vernon soils lie west of the region of true Prairie soils, but they are shown in association with the Kirkland soils. The differentiation between true Prairie soils and soils of the region west of the prairies, to be discussed later, has not been worked out in Oklahoma because very little mapping has been done in that State.

The soils discussed as Cory, Putnam, Grundy, Cherokee, and Kirkland are claypan soils constituting soils without normal profiles. Similar soils occur in association with the other groups of soils, especially with the Gray-Brown Podzolic soils of southern Illinois and also in association with the soils of the Great Plains which will be discussed later. Their profiles are not normal profiles developed under the unmodified influence of the climatic and vegetative environment of the region, but are the product of these, modified in their operation by local factors, one of these being apparently the chemical composition of the parent material. Studies have not yet been carried far enough to warrant a definite conclusion regarding their origin. The profile is morphologically so much like that of the Solonetz soils of the Great Plains that a similarity of origin is suggested. They are local soils, therefore, and in a strict sense belong in the same category as the poorly drained soils of the Gray-Brown Podzolic group or of the Red and Yellow soils of the South, such as the Portsmouth and Leonardtown soils of the older coastal plain or the Clyde and Brookston soils of Indiana.

HOUSTON AND ASSOCIATED SOILS

Another group of soils with imperfectly developed profiles, due also it seems to the peculiar character of the parent material, is mapped in large areas in Texas as Houston soils. These soils occur also in Alabama and were mentioned on page 42. The characteristic area of their occurrence however, is Texas, where their peculiar features are better developed than in Alabama. The surface soil is black to a depth ranging from 6 inches to 2 feet or more in extreme cases. The black color is more dense than the black color of most of the Prairie soils, either normal or otherwise. Under natural conditions, or where the soil has not been disturbed for a short time, the surface is covered with a thin crust. This is underlain at a depth of less than an inch, usually one-half inch, by a crumbly highly granular mass from 1 to 3 inches thick. The material below this, especially when moist, is slightly more dense, though granulation is normally well developed and extends through the depth of the dark-colored layer. The dark-colored layer effervesces in hydrochloric acid on the surface or immediately below it. Beneath the dark-colored layer lie the highly calcareous clays or marls of the region, constituting the parent rock. The soil profile, other than the color profile, has not developed. There has been very slight eluviation and no development of acidity. The surface soil is either neutral or alkaline in reaction.

Associated with the typical Houston soils are soils in which degradation or podzolization has taken place. These soils, in detailed mapping, are identified as members of the Wilson series but on the soil map in this Atlas they are included with the Houston soils. They occur mainly along the eastern border of the Houston belt. They are, as a rule, somewhat lighter in color than the Houston soils, do not have the granulation of the latter, and are somewhat acid in reaction. In many places they have a heavy intractable hard clay layer underlying a grayish layer just below the dark-colored surface soil. They seem to be, in part at least, Houstonlike soils developed in the presence of salts, similar to those which have caused the development of the claypan in the other soils already described, and in part also degraded Houston soils. The belt of Houston soils extends, as shown on the soil map, southwest from near the northeast corner of the State to the city of San Antonio. Beyond that the same geologic formations extend to the vicinity of the Rio Grande, but the soils have been differentiated into another soil group although their characteristics are very much like those of the Houston soils. They will be described as members of the Chernozem soils (p. 75).

LAKE CHARLES AND ASSOCIATED SOILS

Along the Gulf coast of Texas and southwestern Louisiana is a belt of black Prairie soils with a profile and texture much like those of the Houston soils. They have developed from recently uplifted calcareous clays of marine (gulf) origin. The belt in which they occur is not yet entirely well drained, so that the soils owe their black color partly to imperfect drainage and partly to their calcareous parent material. The soils effervesce at slight depth as a rule. They are shown on the map as Lake Charles soils. They occur in a coastal-border belt beginning immediately west of the Mississippi River flood plain in Louisiana, extending for a long distance into Texas. Its width is about 25 miles. The material from which these soils have developed is of very recent geological age, and the soil profile is not developed except for the accumulation of organic matter. The calcium carbonate of the parent material has been only partly removed. The surface soil is black, usually heavy in texture, and has a fairly well developed granular structure. It is underlain by brown or yellowish-brown mottled calcareous clay. The dark-colored layer does not usually effervesce in acid, but the clays beneath effervesce freely.

Lake Charles clay, as a soil, is similar to Houston black clay. Both soils are young, both are black, and, to a considerable extent, both are black because of the high percentage of calcium carbonate in the parent material, which has not yet been leached out or was not at all leached until after the organic matter had been accumulated. Both soils have developed under grass cover. The Lake Charles soils, however, have developed under less perfect drainage than the Houston soils, and the dark color is due in part to this poorly drained condition.

Immediately north of the belt of Lake Charles soils in Texas, and also to a certain extent in southern Louisiana, is a belt of soils mapped as members of the Katy series. These are light-colored soils with a profile much like the profile of the Cherokee soils. The A horizon is light in color and silty in texture. The B horizon consists of heavy, hard tough clay. In poorly drained spots the profile is not fully developed, and in detailed mapping these spots are identified as members of the Edna series. The Katy soils and an associated series identified as Hockley soils seem to constitute a transition from the undeveloped black Lake Charles soils to the light-colored Susquehanna and Lufkin soils of east-central Texas. Morphologically the profile of the Katy soils is essentially like that of the Solonetz soils or "slick spots" of the far West.

COMPOSITION OF PRAIRIE SOILS

Very little work has been done in the study of the chemical composition of the Prairie soils. Aside from the dark color, their characteristics are not such as to demand attention. Their profiles do not have the well-defined features of the Podzolic soils in the eastern part of the United States or of the Chernozems and the soils of the semiarid and arid regions of the western part. Interest in the region of their occurrence has been attracted to the natural vegetation, especially its unusual relation to the climatic environment and to the general environmental conditions rather than to the chemical character of the soils.

COMPOSITION OF CARRINGTON AND SHELBY SOILS

The composition of material from a profile of Carrington silt loam from Butler County, Nebr., is shown in Table 131. A glance at the complete analysis shows a high percentage of alkalies and alkaline earths, especially when compared with the percentages in the Red and Yellow soils, and an extremely slight differentiation of the profile into A and B horizons, based on the relative percentages of silica and the sesquioxides.

Table 131.—*Composition of Carrington silt loam, Butler County, Nebr.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
375503	A	0–12	[a]73.66	0.54	3.62	10.86	0.06	0.96	0.71	1.92	1.06	0.10	0.10	6.48	100.09	0.170	------
			[b]78.73	.58	3.87	11.62	.06	1.03	.76	2.05	1.16	.11	.11	------	100.08	------	------
375504	B	12–30	[a]74.15	.55	4.07	12.37	.07	.95	.89	1.90	1.12	.03	.03	3.87	100.00	.050	------
			[b]77.14	.57	4.23	12.87	.07	.99	.93	1.98	1.16	.03	.03	------	100.00	------	------
375505-6	C	30–48	[a]73.51	.55	4.64	12.64	.13	1.14	.98	1.60	1.18	.12	.03	3.58	100.10	.030	------
			[b]76.24	.57	4.81	13.12	.13	1.18	1.82	1.66	1.22	.12	.03	------	100.08	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter .25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
375503	A	0–12	2.6	5.2	3.8	13.9	23.6	36.6	14.3	100.0
375504	B	12–30	.8	5.2	3.4	9.4	22.2	39.6	19.4	100.0
375505-6	C	30–48	3.1	6.7	4.3	14.5	16.1	30.1	24.6	99.4

[1] Collected by A. W. Goke.
[2] Analyzed by G. J. Hough.
[3] Analyzed by V. Jacquot.

The percentage of clay in the top foot is 14 and of silt is 36.6. The very fine sand could also be included with the silt since most of it is of sufficient size as barely to be classed as sand rather than silt. The percentage of very fine sand is 23.6, and it runs rather high through all the horizons of the profile. The percentage of clay between depths of 12 and 30 inches is 19.4 and in the next layer extending to 48 inches is 24.6. This is a heavy clay layer and lies below the normal level of what would be the B horizon in Podzolic soils. Since the percentage of clay below 60 inches, not shown in the mechanical analysis table, is only 23, it is clear that the heavy layer is not part of the parent material but is a developed horizon, not a normal B horizon. This is a feature widely prevalent in the soils of Nebraska, the origin of which has not yet been determined.

The range in percentage of silica throughout the profile to a depth of 4 feet is only 2, that of iron oxide is a little less than 1, and that of alumina about 1½. The percentage of nitrogen in the top foot of the soil is 0.17, equivalent to an organic-matter content of about 4 per cent. In the Podzolic soils the layer with as much nitrogen as this ranges from 1 to 3 inches in thickness (*12*), but in the Prairie soils this layer ranges from 7 or 8 inches to 15 inches. In this soil it is 10 inches thick, and in the layer below this the nitrogen percentage is still high.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3 and the sum of the molecular equivalents of alkalies and alkaline earths are shown in Table 132.

TABLE 132.—*Carrington silt loam, Butler County, Nebr.*

Sample No.	Horizon	Depth in inches	Ratios: sa	Ratios: sf	Ratios: ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
375503	A	0–12	11.52	53.90	0.517	1.312	0.0240	0.1137	0.0583
375504	B	12–30	10.19	48.32	.455	1.284	.0265	.1262	.0573
375505, 375506	C	30–48	9.88	42.20	.454	1.270	.0306	.1284	.0587

The ratios for the three horizons are as much alike as the percentages in the complete analysis table. The sa ratios indicate a slight increase of alumina relative to silica from horizon A downward. The molecular equivalent composition shows, however, a progressive decrease in number of molecules of both alumina and iron oxide from C through B to A. The number of molecules per unit of weight in B is about 2 per cent less than in C and in A about 11 per cent less. The number of iron oxide molecules in B is about 15 per cent less than in C and in A is about 25 per cent less. No accumulation of molecules of iron oxide in proportion of total weight has taken place in B, although the sf ratio is higher for B than for C.

The ba ratios for A, B, and C are very close together, there being an accumulation of alkalies and lime in the A horizon and some loss in B. The molecular equivalent composition shows an increase by about 1.6 per cent in number of molecules in C, per unit of weight, over those in B, and 1 per cent less in A than in C. According to these results, Carrington silt loam has a very slightly decreased content of bases per unit of weight in B than in C.

The chemical composition of material from the surface soil and subsoil of Carrington loam from Black Hawk County, Iowa, is shown in Table 133 (*15*). The table includes the composition of colloid extracted from each layer. The composition of the colloid, with minor exceptions in CaO and Na_2O, is essentially the same in both layers examined. The sa ratio in the colloid is 3.3, that of the soil in the surface layer is 14.7, and in the subsoil is 15.9.

TABLE 133.—*Chemical composition of soil and colloid from Carrington loam, Black Hawk County, Iowa* [1]

Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Loss on ignition	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	0–12	[a]77.28	0.53	2.89	8.93	0.056	0.84	0.56	1.35	1.15	0.14	0.10	6.52	100.34	0.27	------
		[b]82.66	.57	3.09	9.56	.060	.90	.60	1.44	1.20	.15	.11	------	100.34	------	------
		[c]44.89	.47	7.75	22.59	.057	1.48	1.44	1.36	.22	.28	.19	20.15	101.39	.61	------
		[d]56.20	.59	9.70	28.27	.071	1.86	1.80	1.70	.27	.35	.24	------	101.05	------	------
B	15–36	[a]82.22	.40	2.54	8.78	.016	.80	.55	1.51	1.25	.06	.04	2.27	100.43	.05	------
		[b]84.09	.41	2.60	8.98	.016	.82	.56	1.54	1.28	.06	.04	------	100.39	------	------
		[c]48.04	.65	8.80	25.19	.032	1.29	1.53	.89	.38	.14	.08	13.75	100.77	.20	------
		[d]55.70	.75	10.20	29.20	.036	1.49	1.77	1.03	.44	.16	.09	------	100.86	------	------

[1] Analyzed by W. O. Robinson and R. S. Holmes.

The chemical and mechanical composition of material from a profile of Shelby loam from Fremont County, Iowa, are shown in Table 134.

TABLE 134.—*Composition of Shelby loam, Fremont County, Iowa* [1]

Sample No.	Horizon	Depth	Chemical [2]: SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
336308	A_1	0–6	[a]76.31	0.54	3.17	9.25	0.06	1.02	0.51	1.71	2.12	0.17	0.08	5.77	100.71	0.160	------
			[b]80.98	.57	3.36	9.81	.06	1.08	.54	1.81	2.25	.18	.08	------	100.72	------	------
336309	A_2	6–15	[a]76.27	.54	3.91	10.18	.06	1.04	.55	1.64	1.98	.13	.08	4.61	100.99	.100	------
			[b]79.94	.57	4.10	10.66	.06	1.09	.58	1.72	2.08	.14	.08	------	101.02	------	------
336310	B	16–48	[a]74.70	.60	4.08	11.98	.10	1.02	.69	1.73	1.99	.13	.06	4.27	101.35	.070	------
			[b]78.03	.63	4.26	12.51	.10	1.07	.72	1.81	2.08	.14	.06	------	101.38	------	------
336311	C	48+	[a]66.42	.53	4.33	11.69	.08	6.55	.74	1.68	1.98	.20	.06	7.26	101.52	.010	2.87
			[b]71.62	.57	4.67	12.60	.09	7.06	.80	1.81	2.13	.22	.06	------	101.55	------	------

Sample No.	Horizon	Depth	Mechanical [3]: Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
336308	A_1	0–6	2.2	6.3	5.0	15.7	14.2	39.3	17.2	99.9
336309	A_2	6–15	2.4	8.8	6.6	20.1	13.8	29.4	19.1	100.2
336310	B	16–48	1.6	4.1	3.3	17.4	18.3	36.3	19.4	100.4
336311	C	48+	2.2	5.6	4.0	13.5	13.4	31.5	30.2	100.4

[1] Collected by C. L. Orrben.
[2] Analyzed by G. J. Hough.
[3] Analyzed by V. Jacquot.

Shelby loam is essentially like the Carrington soils in the solum. The profile shows the composition of the unleached or only partly leached parent material which in this locality lies below a depth of 4 feet. The Butler County, Nebraska, sample of Carrington silt loam does not show the composition of the unleached parent material.

The surface layer in the Fremont County sample of Shelby loam, extending to a depth of 6 inches only, seems to have been somewhat more degraded or leached than the corresponding layer of Carrington silt loam in Butler County, Nebraska.

The percentage of clay in the surface layer to a depth of 6 inches is 17, but from 6 to 48 inches it stands at 19. Below that it is much higher. The deepest layer is below the solum. It was stated in the general description of the Carrington and Shelby soils (p. 63) that the parent material of the Shelby soils is usually heavier than that of the Carrington. The percentage of sand coarser than fine sand is very low in the Shelby soils, but the percentage of sand of all classes is much higher than in Carrington silt loam.

In this profile the percentage of alumina increases from the surface downward, the maximum being in the layer deeper than 48 inches. The iron oxide percentage also increases progressively from the surface downward, the difference between layers 1 and 2 being greater than that between 2 and 3.

The percentages of alkalies and alkaline earths are a little higher than in Carrington silt loam, especially CaO and Na_2O. The percentage of nitrogen is practically the same as in the Carrington soils, the second layer showing a higher percentage than the corresponding layer in the Carrington, because the top of this layer in the Shelby soils lies still within the dark-colored layer.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, and Al_2O_3 and the sum of the molecular equivalents of the alkaline earths and CaO are shown in Table 135.

TABLE 135.—*Shelby loam, Fremont County, Iowa*

Sample No.	Horizon	Depth in inches	Ratios: sa	Ratios: sf	Ratios: ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
336308	A_1	0–6	14.03	63.83	0.778	13.490	0.0210	0.0963	0.0753
336309	A_2	6–15	12.74	51.67	.679	1.332	.0256	.1043	.0713
336310	B	16–48	10.63	48.53	.586	1.300	.0266	.1215	.0723
336311	C	48+	9.65	40.57	1.455	1.192	.0292	.1233	.1796

The sa and sf ratios increase from horizon C upward. Silica, as shown by the complete analysis as well as by the ratios, increases upward, and the sesquioxides increase downward, the high CaO content in horizon C not being sufficient to reduce it in that layer below that in the higher layers. No accumulation of iron oxide has taken place in A_2 or B, the number of molecules per unit of weight decreasing progressively from C upward, the maximum decrease taking place between A_2 and A_1. The alumina decreases from C upward, the maximum decrease taking place from A_2 to A_1. It is apparent that some alumina has been shifted from A_2 to B, but the iron oxide removed has gone out of the soil entirely.

A well-marked increase of bases has taken place in A_1, a similar increase having taken place in Carrington silt loam also. The lower percentage of bases in A_2 and B is due to the high CaO in C, the parent material, and the concentrated bases in A are due to the action of vegetation. There being no significant accumulation of alumina in B, there could be no compensating increase of bases in B even if the colloidal alumina in that horizon were more absorptively active than the colloidal alumina in the Red and Yellow soils. It is apparent that the lower number of molecules of the bases in layer B of these uneluviated or very slightly eluviated soils, does not have the same significance as the still lower number, relative to those in A and C, in the B horizons of the highly eluviated Red and Yellow soils. There is no carbonate in the C horizon of these latter soils, and the percentage of organic matter in A, taking the horizon as a whole, is so low that the accumulation of bases due to this is very small, though definite, as has already been seen. Were the highly accumulated colloidal material in the B horizon strongly absorptive for bases or the leaching power of the climate less effective, the percentage of bases in B should easily attain an amount higher than that in A or C.

COMPOSITION OF MARSHALL AND TAMA SOILS

The Marshall soils have developed from silty parent materials, presumably wind blown. They occur mainly along Missouri River in Iowa, Nebraska, Kansas, and Missouri. The parent material is calcareous but is often leached of its carbonates to considerable depth.

The chemical and mechanical composition of material from a profile of Marshall silt loam in Fremont County, Iowa, are shown in Table 136.

TABLE 136.—*Composition of Marshall silt loam, Fremont County, Iowa* [1]

Sample No.	Horizon	Depth	Chemical [2]: SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct*	*P. ct.*
336301	A	0–10	[a]72.63	0.63	3.14	12.03	0.10	0.79	0.82	2.23	1.36	0.12	0.12	6.01	99.98	0.167	------
			[b]77.30	.67	3.34	12.79	.11	.84	.87	2.37	1.45	.13	.13	------	100.08	------	------
336302	B	10–30	[a]72.79	.66	3.96	12.77	.118	.70	1.04	2.08	1.32	.10	.08	4.46	100.08	.086	------
			[b]76.20	.69	4.14	13.36	.124	.73	1.09	2.18	1.38	.10	.08	------	100.07	------	------
336303	C_1	30–60	[a]73.68	.70	3.67	12.93	.086	.90	1.13	1.94	1.26	.14	.03	3.27	99.74	.037	------
			[b]76.17	.72	3.79	13.36	.089	.93	1.17	2.00	1.30	.14	.03	------	99.70	------	------
336304	C_2	60+	[a]73.56	.61	3.22	12.33	.94	1.73	1.43	2.43	1.60	.16	.02	2.94	100.12	.015	------
			[b]75.79	.63	3.32	12.71	.97	1.78	1.47	2.50	1.65	.16	.02	------	100.13	------	------

Sample No.	Horizon	Depth	Mechanical [3]: Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
336301	A	0–10	0.0	0.0	0.0	0.1	3.1	68.6	28.1	99.9
336302	B	10–30	.0	.0	.1	.2	2.6	67.6	29.5	100.0
336303	C_1	30–60	.0	.1	.0	.1	3.3	67.4	29.0	99.9
336304	C_2	60+	.0	.1	.1	.1	2.8	73.8	23.1	100.0

[1] Collected by C. L. Orrben.
[2] Analyzed by G. Edgington.
[3] Analyzed by L. T. Alexander.

The profile was sampled to a depth of more than 60 inches. The mechanical analysis table, based on an analysis of material after removing organic matter by treatment with hydrogen peroxide, shows a profile very uniform to a depth of 5 feet. The percentages of silt have a maximum difference of 1 per cent, those of clay of 1.4 per cent. In the loose silty parent material below a depth of 60 inches the percentage of silt is 6 per cent higher than in the other horizons and that of clay is correspondingly lower.

The percentages of SiO_2, Fe_2O_3, and Al_2O_3 in the upper three layers (the solum) are very uniform throughout, but their differences are greater than those of the

mechanical profile. The range in percentages of alumina is 2.7, of iron oxide nine-tenths of 1 per cent, and of SiO_2 is 2.95. The percentage of sesquioxides in the surface layer shows that slight removal has taken place, but there is no indication that any of the removed alumina has accumulated in horizons B or C_1. The molecular equivalent value for iron oxide in B and C_1 indicates that some iron oxide has accumulated in those two layers. The content of nitrogen is the same as in the Carrington and Shelby soils.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 137.

TABLE 137.—*Marshall silt loam, Fremont County, Iowa*

Sample No.	Horizon	Depth in inches	Ratios: sa	Ratios: sf	Ratios: ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
336301	A	0–10	10.280	61.33	0.507	1.288	0.0209	0.1254	0.0620
336302	B	10–30	9.700	48.75	.446	1.270	.0259	.1310	.0581
336303	C_1	30–60	9.690	52.8	.448				
336304	C_2	60+	10.137	60.26	.603	1.263	.0201	.1246	.0848

Horizon C_2 is essentially identical with horizon C_1 in chemical composition, though they differ in mechanical composition. The sf ratios show a progressive decline in iron oxide from the parent material upward through B but an increase in A. The molecular equivalent composition shows, however, that the number of molecules of iron oxide per unit of weight in B is well above the number in C_2 or A. The number in A is essentially the same as that in C_2. The number of molecules of alumina is very slightly greater in B also, whereas those in A and C_2 are practically the same. Since the mechanical analysis shows a lower percentage of clay and an even lower percentage of silt and clay combined in the C_2 horizon than in A, the reason for the larger number of molecules of alumina, per unit of weight, in B than in A is not clear. The number of molecules of alkalies and lime in the three horizons is of the same order as in the Shelby and Carrington soils, but the range is different.

Colloid was extracted from material of the B horizon of Marshall silt loam from Nebraska but not from the identical locality of the foregoing sample. The chemical composition of the colloid, together with that of the whole soil, are shown in Table 138.

TABLE 138.—*Chemical composition of Marshall silt loam, Mynard, Cass County, Nebr.*[1 2]

Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
	Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
A	0–14	[a]72.06	0.67	3.66	11.18	0.05	0.90	0.66	2.66	1.02	0.21	0.12	6.94	100.13	------	------
		[b]77.43	.72	3.93	12.03	.05	.96	.71	2.86	1.09	.23	.13	------	100.12	------	------
B	14–36	[a]70.22	.71	4.76	12.91	.10	1.03	1.12	2.29	1.14	.30	.06	5.42	100.06	------	------
		[b]74.26	.75	5.00	13.65	.10	1.09	1.18	2.41	1.20	.32	.06	------	99.98	------	------
		[c]48.18	.50	10.03	22.00	.11	1.36	2.07	.15	.21	.06	.03	13.28	97.98	------	------
		[d]55.57	.53	11.57	25.37	.13	1.57	2.39	.17	.24	.07	.03	------	97.64	------	------

[1] Collected by A. H. Meyer.
[2] Analyzed by W. O. Robinson and R. S. Holmes.

The mechanical composition of the sample has not been determined, and no material from below the solum was collected. The chemical composition of the whole soil shows a difference in content of alumina of 1.6 per cent between the surface soil and subsoil, and in iron oxide a little more than 1 per cent. This profile seems to show some eluviation.

The percentages of alkalies and alkaline earths are essentially the same as in the previously examined profile.

The percentages of sesquioxides in the colloid are, of course, much higher than in the soil. The percentage of magnesia is much higher in the colloid than in the soil, that of CaO a little higher, and that of potash and Na_2O are much lower. The sa ratio is 3.72, more than twice that in the colloid from the B horizon of the Red soils. The same ratio in the colloid from the subsoil of Carrington loam (p. 66) is 3.24.

The Tama soils, mainly silt loam, have developed from silts, presumably wind blown, but seemingly older than those from which the Marshall soils have developed. The Tama soils are usually regarded as more thoroughly leached and more acid than the Marshall soils.

The chemical and mechanical composition of material from a profile of Tama silt loam from near Newton, Iowa, are shown in Table 139. The upper 6 inches of the A horizon was omitted, but the percentage of organic matter is high to a depth of 24 inches.

TABLE 139.—*Composition of Tama silt loam, Newton, Iowa*[1]

Sample No.	Horizon	Depth	Chemical[2]: SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34777	A_2	6–12	[a]70.80	0.69	3.82	11.48	0.13	0.98	0.92	2.05	0.93	0.18	0.15	8.39	100.52	0.240	------
			[b]77.27	.75	4.17	12.53	.14	1.07	1.00	2.24	1.01	.20	.16	------	100.54	------	------
34778	A_3	14–24	[a]70.56	.67	3.91	12.15	.14	.79	.88	2.01	.91	.14	.15	7.90	100.21	.210	------
			[b]76.58	.73	4.24	13.19	.15	.86	.95	2.18	.99	.15	.16	------	100.18	------	------
34779	B	24–50	[a]69.90	.72	5.09	14.30	.12	.86	1.33	2.01	.91	.10	.09	5.07	100.50	.070	------
			[b]73.61	.76	5.36	15.06	.13	.91	1.40	2.12	.96	.11	.09	------	100.51	------	------
34780	C_1	50–70	[a]70.21	.69	4.78	13.63	.13	.76	1.14	1.97	.88	.10	.09	5.85	100.23	.110	------
			[b]74.57	.73	5.04	14.48	.14	.81	1.21	2.09	.93	.11	.10	------	100.21	------	------
34781	C_2	90+	[a]71.10	.65	5.03	13.90	.14	.93	1.36	2.00	.95	.15	.10	4.16	100.47	.050	------
			[b]74.18	.68	5.25	14.50	.15	.97	1.42	2.09	.99	.16	.10	------	100.49	------	------

Sample No.	Horizon	Depth	Mechanical[3]: Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34777	A_2	6–12	0.1	0.2	0.2	0.2	0.6	61.8	37.0	100.1
34778	A_3	14–24	.1	.3	.2	.2	.7	60.0	38.4	99.9
34779	B	24–50	.0	.1	.1	.3	1.0	55.8	42.7	100.0
34780	C^1	50–70	.1	.3	.2	.3	.8	57.4	41.0	100.1
34781	C_2	90+	.0	.1	.1	.3	1.2	59.1	39.2	100.0

[1] Collected by C. F. Marbut.
[2] Analyzed by G. Edgington.
[3] Analyzed by L. T. Alexander.

The mechanical composition, determined on the basis of the mineral material after organic matter had been removed, shows slight eluviation and a faint development, therefore, of A and B horizons. The percentages of clay in the A_3 and B horizons differ by 5.7 per cent, that in A_3 being a little lower than that in C_2. The percentages of silt range between 56 and 62 per cent and of clay and silt combined between 98.3 and 98.8 per cent.

The percentage of alumina in what may be called B is a little more than 15 and that in A_2 is 12.53. That in C_1 is 14.48. The differences are very slight. The percentages of iron oxide range from 4.17 in A_2 to 5.36 in B. The percentages of alkalies and alkaline earths are high, as is usual in the prairie soils, but no carbonates are present at a depth of less than about 10 feet.

The percentage of nitrogen is higher than in the previously examined prairie soils, that in B being higher than in the surface layers of the Marshall and Carrington soils. Where the Marshall soils lie on smooth areas the content of nitrogen is about the same as that in the Tama soils.

The several ratios and the molecular equivalent composition for SiO_2, Fe_2O_3, Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 140. The slight eluviation indicated in the complete analysis is shown in the sa and sf ratios.

TABLE 140.—*Tama silt loam, Newton, Iowa*

Sample No.	Horizon	Depth in inches	Ratios: sa	Ratios: sf	Ratios: ba	Molecular equivalent composition: SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
34777	A_2	6–12	10.48	49.10	0.482	1.28	0.0261	0.122	0.0592
34778	A_3	14–24	9.87	47.86	.421	1.27	.0265	.129	.0545
34779	B	24–50	8.31	36.40	.367	1.22	.0335	.147	.0542
34781	C_2	90+	8.69	37.42	.390	1.23	.0328	.142	.0555

The sa ratios as well as the molecular equivalent composition show higher silica content in A_2 than in C_2, the former showing a difference of 20 per cent, the molecular equivalent composition indicating only about 0.4 per cent.

The molecular equivalent composition indicates a very slightly higher content of both alumina and iron oxide in B than in C but considerably greater differences between A_2 and B in these respects, these differences being more than ten times as large as the former. As usual, eluviation seems to have removed more material from the A horizon than has been gained by B.

The relative number of molecules of bases is about 10 per cent higher in A_2 than in B and a little higher in C_2 than in B. The higher percentage in A_2 than in B is due to the action of vegetation in increasing the content of organic matter in A_2 and along with it that of the bases.

Very little is known in detail concerning the composition of the Summit soils, constituting in general, as shown on the soil map in this ATLAS, the Prairie soils with approximately normal profiles in eastern Kansas and western Missouri, south of the glacial boundary. It was explained, under the general profile description of these soils, that, as shown on the map, a rather wide range of soil character has been included in them. On account of the very limited amount of detailed soil mapping that has been done in eastern Kansas, the differentiation of the soils of the region has not been well worked out.

The chemical and mechanical composition of a profile of Summit clay from Wellington, Kans., are shown in Table 141.

TABLE 141.—*Composition of Summit clay, Wellington, Kans.*[1]

Sample No.	Horizon	Depth	Chemical[2]: SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29910	A_1	0–12	[a]71.60	0.81	3.56	11.45	0.06	0.97	0.86	2.42	1.04	0.09	0.11	6.60	99.57	0.090	------
			[b]76.68	.87	3.81	12.27	.06	1.04	.92	2.59	1.11	.10	.12	------	99.57	------	------
29911	A_2	12–23	[a]74.28	.81	3.46	10.55	.06	.84	.76	2.43	1.08	.07	.08	5.35	99.77	.120	------
			[b]78.49	.86	3.66	11.14	.06	.89	.80	2.57	1.14	.07	.08	------	99.76	------	------
29912	B	24–36	[a]70.67	.74	4.35	13.12	.06	.85	.97	2.32	.92	.07	.04	5.37	99.48	.070	------
			[b]74.68	.78	4.61	13.89	.06	.90	1.03	2.46	.97	.07	.04	------	99.49	------	------
29913	C	36–50	[a]70.93	.77	3.91	12.30	.06	1.56	1.06	2.43	1.07	.06	.04	5.72	99.91	.050	0.59
			[b]75.21	.82	4.15	13.04	.06	1.65	1.12	2.58	1.13	.06	.04	------	99.91	------	------

Sample No.	Horizon	Depth	Mechanical[3]: Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29910	A_1	0–12	0.0	0.4	0.3	2.7	4.3	57.5	34.4	99.6
29911	A_2	12–23	.0	.3	.3	4.1	15.2	49.9	29.5	99.3
29912	B	24–36	.0	.3	.2	.7	16.1	38.3	44.2	99.8
29913	C	36–50	.0	.4	.5	.8	7.7	50.2	40.1	99.7

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough.
[3] Analyzed by J. B. Spencer.

Although this soil has not been definitely identified as a member of the Summit series, its composition is fairly representative, since it is a well-developed normal soil of the Summit region. A slight accumulation of alumina and clay in the layer between 24 and 36 inches may indicate slight eluviation, but it is more probable that it indicates the presence of a very low content of deflocculating salts in the parent material.

The mechanical composition shows 34.4 per cent of clay in the surface layer and 44 per cent in B. The percentage of very fine sand is higher than in the Marshall and Tama soils, but the percentage of sands of all classes is low, amounting to a maximum of 20 per cent in A_2. The total percentages of silt and clay range from 79 in A_2 to 92 in A_1.

The percentages of clay and alumina are each higher in A_1 than in A_2. That of iron oxide is also higher. This is in part an expression, so far as mechanical analysis is concerned, of the finely divided colloidal organic matter. This would not, however, account for the higher percentages of alumina and iron oxide. These may possibly be due to accumulated dust, caught in the grass cover. Since A_1 is 12 inches thick the one thing certain is the absence of eluviation. The slightly higher percentage of alumina in A_1, as already explained, may be due to the presence of

deflocculating salts in extremely small quantities. Whatever may be the explanation of its occurrence it is most probably the same as that of the heavy clay layer so widely prevalent in the subsoils of the prairies and Great Plains.

The content of alkalies and alkaline earths is high, there being some carbonate below a depth of 40 inches. The content of organic matter is not high, but it remains relatively high to a depth of nearly 2 feet. This is a well-defined Prairie soil.

The chemical and mechanical composition of material from a profile of Prairie soil at Belleville, Republic County, Kans., very near the western boundary of the prairies, are shown in table 142.

TABLE 142.—*Composition of Summit clay loam, Belleville, Kans.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO$_2$	TiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$	MnO	CaO	MgO	K$_2$O	Na$_2$O	P$_2$O$_5$	SO$_3$	Ignition loss	Total	N	CO$_2$ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29846	A$_1$	0–12	[a]73.35	0.72	2.86	11.51	0.06	1.16	0.78	2.82	1.31	0.14	0.10	5.57	100.38	0.140	------
			[b]77.68	.76	3.03	12.17	.06	1.23	.83	2.99	1.39	.15	.11	------	100.41	------	------
29847	A$_2$	12–20	[a]70.95	.73	3.35	12.43	.07	1.23	.93	2.68	1.10	.13	.08	5.83	99.51	.110	------
			[b]75.33	.78	3.56	13.20	.07	1.31	.99	2.85	1.17	.14	.08	------	99.48	------	------
29848	B	20–40	[a]66.75	.68	4.82	14.84	.11	1.18	1.36	2.91	1.14	.16	.07	5.50	99.52	.070	------
			[b]70.65	.72	5.10	15.70	.12	1.25	1.44	3.08	1.21	.17	.07	------	99.51	------	------
29849	C	40+	[a]68.91	.67	3.88	13.65	.05	2.23	1.36	2.79	1.20	.22	.08	4.55	99.59	.040	------
			[b]72.15	.70	4.06	14.30	.05	2.34	1.42	2.92	1.26	.23	.08	------	99.51	------	0.41

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29846	A$_1$	0–12	0.0	0.0	0.0	0.1	35.6	39.7	24.8	100.2
29847	A$_2$	12–20	0	0	0	0	38.7	30.7	30.6	100.0
29848	B	20–40	0	0	0	.2	30.9	17.2	51.4	99.7
29849	C	40+	0	0	0	.1	31.3	26.6	42.0	100.0

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough.
[3] Analyzed by J. B. Spencer.

This soil has not yet been given definite status as a series since no detailed work has been done in this county. It is a soil in which the clay subsoil, very faintly expressed in the soil at Wellington, Kans., is much more strongly expressed. The percentages of clay in the soil layers from the surface downward are 25, 30, 51, and 42. The higher percentage in the third layer is well expressed. The rest of the material consists, in all the layers, of silt and very fine sand.

The percentages of alumina and iron oxide run parallel, in the profile, with those of clay. The percentages of alkalies and alkaline earths are high throughout, there being a low percentage of carbonate below a depth of 40 inches. The percentage of organic matter (nitrogen) is relatively high and continues moderate or high to a depth of 20 inches.

The third layer, containing the highest percentage of both alumina and iron oxide, does not have the appearance in the field of the B horizon of Podzolic soils. It is dark grayish and breaks into roughly cubical rather large blocks, on the outcrop, rather than into the very small angular structure particles in B horizons.

The soil at Belleville should probably be interpreted as a soil without a normal profile. Soils with similar but much more extremely developed profiles cover large areas in the prairies.

The Chariton soils occupy a relatively small area but the profile is essentially the same as that of the Putnam soils. They may be considered as Putnam equivalents developed on terraces. The chemical and mechanical composition of material from the solum of a Chariton profile are shown in Table 143.

TABLE 143.—*Composition of Chariton silt loam, East Trenton, Mo.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO$_2$	TiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$	MnO	CaO	MgO	K$_2$O	Na$_2$O	P$_2$O$_5$	SO$_3$	Ignition loss	Total	N	CO$_2$ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
343743	A$_1$	0–7	[a]76.65	0.71	2.54	8.47	0.12	0.72	0.80	1.89	1.46	0.14	0.08	6.42	100.00	0.200	------
			[b]81.88	.76	2.71	9.05	.13	.76	.85	2.02	1.56	.15	.09	------	99.98	------	------
343744	A$_2$	7–18	[a]76.25	.30	3.68	10.70	.22	.61	.62	1.99	1.39	.12	.13	3.99	100.00	.160	------
			[b]79.41	.31	3.83	11.14	.23	.64	.65	2.07	1.45	.12	.14	------	100.01	------	------
343745	B	18–36	[a]68.63	.61	5.52	14.60	.23	.91	1.33	.78	.50	.17	.09	6.63	100.00	.110	------
			[b]73.49	.65	5.91	15.64	.25	.97	1.43	.83	.54	.18	.10	------	99.99	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
343743	A$_1$	0–7	0.6	1.6	1.2	1.2	2.1	76.8	16.7	100.2
343744	A$_2$	7–18	1.0	2.0	1.2	1.0	2.4	73.8	18.9	100.3
343745	B	18–36	.3	1.4	.9	1.2	2.5	48.5	45.4	100.2

[1] Collected by A. T. Sweet.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, June 19, 1917.
[3] Analyzed by J. W. Bomboy.

The mechanical composition table shows a much higher percentage of clay in the third layer than in either of the others. It is almost three times as much as in the first layer. Silt constitutes practically all the rest of the material, the sands amounting to only about 6 per cent.

The percentages of alumina and iron oxide run parallel with those of clay. Removal of material from the first two layers has presumably taken place, but since the composition of the parent material is not shown it is not possible to show this definitely.

These soils are somewhat podzolic, but the third layer is not a normal B horizon of a normal Podzolic soil.

The percentage of calcium is low, but the percentages of potash and Na$_2$O are high.

The Putnam soils occupy large areas in northeastern Missouri and parts of adjacent States. The profile is similar to that of the Chariton soils. They occur in smooth, nearly flat upland areas. The chemical and mechanical composition of material from a Putnam profile from Boone County, Mo., are shown in Table 144.

TABLE 144.—*Composition of Putnam silt loam, Columbia, Boone County, Mo.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO$_2$	TiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$	MnO	CaO	MgO	K$_2$O	Na$_2$O	P$_2$O$_5$	SO$_3$	Ignition loss	Total	N	CO$_2$ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34748	A$_1$	0 – 6	[a]78.04	0.75	2.56	8.81	0.12	0.64	0.46	1.63	1.02	0.08	0.07	5.82	100.00	0.200	------
			[b]82.87	.79	2.72	9.36	.13	.68	.49	1.73	1.08	.08	.07	------	100.00	------	------
34749	A$_2$	6 –12½	[a]78.28	.74	3.21	10.26	.08	.58	.53	1.71	1.06	.11	.05	3.39	100.00	.100	------
			[b]81.02	.77	3.32	10.62	.08	.60	.55	1.77	1.10	.11	.05	------	99.99	------	------
34750	B	12½–27½	[a]70.27	.75	4.76	15.10	.05	.85	1.23	1.96	1.14	.09	.02	3.78	100.00	.050	------
			[b]73.03	.78	4.95	15.68	.05	.88	1.28	2.03	1.18	.09	.02	------	99.97	------	------
34751	C	27½–36	[a]72.11	.74	4.35	14.32	.08	1.05	1.11	2.20	1.26	.10	.01	2.67	100.00	.030	------
			[b]74.09	.76	4.46	14.71	.08	1.08	1.14	2.26	1.29	.10	.01	------	99.98	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34748	A$_1$	0 – 6	0.8	1.3	0.4	0.3	0.9	71.0	25.2	99.9
34749	A$_2$	6 –12½	1.1	1.9	.6	.4	.8	68.6	26.7	100.1
34750	B	12½–27½	.0	.1	.1	.2	.4	39.8	59.4	100.0
34751	C	27½–36	.1	.5	.4	.5	.7	58.2	39.8	100.2

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Mar. 22, 1918.
[3] Analyzed by H. W. Lakin.

This profile was sampled below the heavy clay layer, but the material has been leached and well decomposed to great depths. The percentages of clay from the surface downward are 25, 27, 59, and 40. Those of silt are 71, 69, 40, and 58. These two classes of materials constitute the entire soil, with the exception of a very small percentage of sand.

The percentages of alumina and iron oxide run parallel, remarkably so, with those of clay.

This soil is acid, and shifting of material has taken place. Like the Chariton profile, however, the third layer is not a normal B horizon. It differs in tenacity, in its breakage into subcubical blocks, and in its color. Each block is coated with dark-colored material to greater or less extent.

The percentage of CaO is relatively low, but the percentages of potash and Na$_2$O are moderately high.

Cherokee soils have profiles similar to those of the Putnam soils. They cover important areas in southwestern Missouri, southeastern Kansas, and northeastern Oklahoma. They have developed from material accumulated by the decomposition of shales of Paleozoic age.

The chemical composition of a sample of Cherokee silt loam from Cherokee County, Kans., and the mechanical composition of a sample of the same soil from Labette County are shown in Table 145.

TABLE 145.—*Composition of Cherokee silt loam, Kansas*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO$_2$	TiO$_2$	Fe$_2$O$_3$	Al$_2$O$_3$	MnO	CaO	MgO	K$_2$O	Na$_2$O	P$_2$O$_5$	SO$_3$	Ignition loss	Total	N	CO$_2$ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
27890	A$_1$	0–6	[a]86.96	0.69	2.86	4.69	0.07	0.71	0.43	0.91	1.07	0.07	0.08	2.96	101.50	0.113	------
			[b]89.61	.71	2.95	4.83	.07	.73	.44	.94	1.10	.07	.08	------	101.53	------	------
27891	A$_2$	6–16	[a]85.13	.74	3.49	5.84	.09	.65	.49	1.00	1.16	.07	.07	2.40	101.13	.090	------
			[b]87.22	.77	3.57	5.98	.09	.67	.50	1.02	1.19	.07	.07	------	101.15	------	------
27892	B	16–28	[a]69.30	.74	4.65	15.06	.02	.77	1.07	1.20	1.10	.10	.18	6.90	101.09	.134	------
			[b]74.41	.79	4.99	16.17	.02	.83	1.15	1.29	1.18	.10	.19	------	101.12	------	------
27893	C	28–40	[a]67.82	.72	4.86	16.74	.02	.80	1.14	1.11	1.04	.11	.23	5.19	99.78	.089	------
			[b]71.53	.76	5.12	17.65	.02	.84	1.20	1.17	1.10	.12	.24	------	99.75	------	------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
381807	A	0–18	0.2	0.8	0.5	0.8	3.6	72.5	21.7	100.1
381808	B	18–26	.0	.1	.1	.5	1.8	44.2	53.2	99.9
381809	C	26–64	.0	.1	.2	.6	2.7	49.4	47.0	100.0

[1] Chemical analyses of a sample from Cherokee County; mechanical analyses of a sample from Labette County.
[2] Collected by E. W. Knobel, analyzed by E. C. Hall.
[3] Analyzed by H. W. Lakin.

The percentages of clay are 22, 53, and 47. Those of silt are 72, 44, and 49.

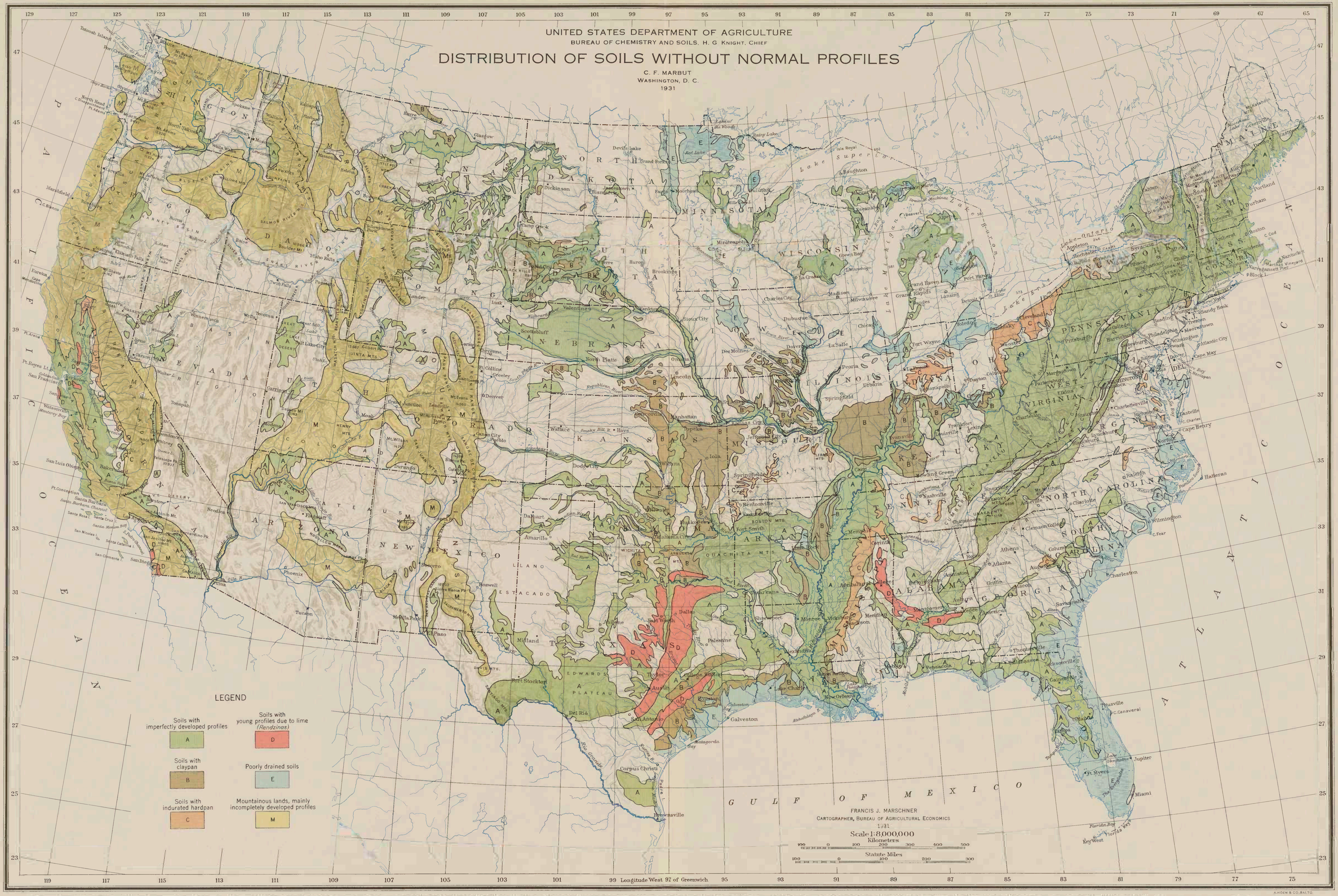
The chemical analysis was made of material from a different but nearby locality and was taken in four layers instead of in three. The sample from which the mechanical analysis was made is a carefully collected sample and shows the features of the horizons clearly. The chemical analysis distinguishes the upper, lighter textured, part of the soil from the lower heavier part, but the second and third layers are less clearly separated as regards texture than in the other sample.

The difference in alumina content between the second and third layers is very great. That of iron oxide is important but not so great.

The percentages of alkalies and alkaline earths are lower than in the Putnam soil.

Houston black clay is an undeveloped Prairie soil. It is a typical Rendzina, a young soil developed and developing from calcareous marls.

The chemical and mechanical composition of a sample from a profile of Houston black clay at Reinhardt, Tex., are shown in Table 146. The mechanical analysis table shows this to be a very heavy soil, more than 80 per cent of the total mass consisting of silt and clay.



The areas without normal profiles are approximate in size only. They indicate areas in which soils without normal regional profiles are dominant rather than exclusive. Within the Appalachian region, for example, shown as a large area of imperfectly developed profiles, a large aggregate area contains soils with normal profiles, but any given area of such soils is small. The areas characterized by soils with imperfectly developed profiles are mainly areas with soils of incompletely developed profiles. The dominant soils are developing normally, but have not yet reached a stage of development marked by the presence of well developed profiles. This group includes the main areas of very sandy soils, such as those of the Sand Hills of Nebraska. Uncolored areas have soils with normal profiles.

TABLE 146.—*Composition of Houston black clay, Reinhardt, Tex.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
445405	1	0–6	[a]55.20	0.64	3.90	10.45	0.20	11.31	1.44	1.44	0.19	0.15	0.09	15.12	100.13	0.170	6.90
			[b]65.02	.75	4.59	12.31	.24	13.32	1.70	1.70	.22	.18	.11	------	100.14	------	------
445406	2	6–14	[a]48.92	.52	4.07	10.78	.16	14.62	1.50	1.38	.21	.17	.15	17.96	100.44	.180	10.10
			[b]59.60	.63	4.96	13.13	.19	17.81	1.83	1.68	.26	.21	.18	------	100.47	------	------
445407	3	14–26	[a]30.19	.43	3.17	7.80	.11	29.34	1.19	.94	.14	.17	.13	26.90	100.51	.100	21.20
			[b]41.21	.59	4.33	10.64	.15	40.06	1.63	1.29	.19	.23	.18	------	100.50	------	------
445408	4	26–40	[a]14.20	.23	2.13	4.77	.04	42.27	.82	.55	.30	.09	.10	35.20	100.70	.050	31.30
			[b]21.91	.35	3.27	7.34	.06	64.98	1.26	.85	.48	.14	.15	------	100.77	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
445405	1	0–6	0.0	0.8	0.6	5.5	12.8	37.6	42.5	99.8
445406	2	6–14	.4	1.3	.8	7.2	11.6	40.9	37.7	99.9
445407	3	14–26	1.4	1.5	.6	4.2	10.4	49.4	32.6	100.1
445408	4	26–40	.7	.6	.2	3.0	10.9	51.9	32.6	99.9

[1] Collected by W. T. Carter and H. H. Bennett.
[2] Analyzed by G. J. Hough.
[3] Analyzed by V. Jacquot and J. B. Spencer.

The content of sesquioxides is not high and that of silica is low but not low enough to demand special attention, considering the high percentage of clay present. The content of organic matter expressed in the table as nitrogen is only about 4½ per cent, but it extends, without decrease, to a depth of 14 inches and is relatively high to a depth of a little more than 2 feet.

The content of lime carbonate is the most striking feature of the soil. In the surface horizon, CO_2 from carbonates amounts to 7 per cent and in the parent marl, below 26 inches, the percentage of carbonate is nearly 80. The content of magnesia is low and that of potash relatively so.

This soil lies in a region with a rainfall which ranges from 30 to 35 inches, but podzolization has not begun. It is a grassland region, the lack of forests being probably determined in part at least, by the high content of carbonate in the soil, which renders it toxic to most trees.

DEVELOPMENT OF THE PODZOLIC SOILS

Tables 147, 148, 149, and 150, showing sa, sf, fa, and ba ratios and the pH have been compiled by bringing together in three tables all the ratios for each of the main Podzolic groups—Podzols, Gray-Brown Podzolic soils, and Red and Yellow soils—described in preceding pages, in order to simplify their comparison. In addition to the ratios used in preceding tables, a fourth ratio, that of iron oxide to alumina (fa), is shown. Ratios for the prairie soils are shown in table 150.

Silicon, aluminum, and iron are not only the constituents of 75 to 95 or more per cent of the soil mass but, together with the bases present, the changes in amount of these constituents and their shifting from one place in the soil profile to another, constitute the most important mass changes that take place in the inorganic material of the soil during its development. A measure of these losses, gains, and shiftings constitutes a measure of the results of soil-developing processes. These shiftings and changes are best expressed by the several ratios shown in the tables.

These ratios have been obtained by computation from the results of complete analyses of the whole soil. They include not merely the ratios of these constituents in the fully decomposed rock materials of the soils, but of all the materials present including, in many cases, several kinds of undecomposed minerals and in practically all cases a considerable percentage of quartz. The ratios for the separate horizons can not, therefore, be accepted as a measure, in any sense, of the state of decomposition of the material, except in the few cases where they express the ratios in colloid material. Although the foregoing is true, these ratios express the relationships of the several horizons, or layers, one to the other, as well or approximately as well as would ratios computed from colloid materials. This is shown by comparing the ratios of the colloid materials with those of the whole soil from which the colloid was derived.

In the table of ratios for the Podzols, those for the Becket fine sandy loam show a loss of both alumina and iron oxide from horizon A compared with the silica in both whole soil and colloid. The percentages of accumulation in soil and colloid are not the same, especially those of alumina, that in the whole soil being considerably higher than in the colloid, probably indicating some mechanical shifting of undecomposed feldspathic particles larger than colloid particles. On the other hand, the apparent accumulation of iron oxide in the B horizons of soil and colloid, above the amounts in the C horizons, compared with silica, is five times as high in the colloid as in the whole soil, probably an expression of the more thorough decomposition of the iron-bearing minerals than of the feldspathic minerals. This relationship of iron-oxide accumulation, compared with that of alumina, is clearly brought out in the ratios of these two constituents (fa) in Table 147, in which it is shown that the iron-oxide accumulation in the B horizon of the colloid, compared with alumina, is about ten times greater than in the same horizon of the whole soil. It is apparent, therefore, that the ratios in both whole soils and their colloids point in the same direction, but those of the colloid point more strongly than those of the whole soil.

The text accompanying the soil map of the United States in this number of the ATLAS OF AMERICAN AGRICULTURE is primarily descriptive rather than interpretational. Since, however, the content of chemical data is very large and constitutes probably the largest body of such data ever brought together in one publication, representing a correspondingly wide range of soils, prepared from samples carefully collected by horizons from localities selected with equal care, it would be wholly unjustifiable not to call attention to certain conclusions clearly suggested by the data. Within the limits imposed by the nature of the data (whole soils rather than colloid), the opportunity presented by them for drawing conclusions regarding the changes in composition brought about by the operation of the Podzolic process is great because a greater quantity of data is now available than has previously been presented.

The general features of Podzols and Podzolic soils have been described many times. Glinka [22] describes a number of profiles which he regards as characteristic and gives also a long list of references to the literature. He states that the gray color of the surface soil is characteristic, basing this statement on the character of the surface soil to which the Russian peasants applied the name Podzol originally. Literally the term Podzol means ashy soil. The typical gray soils of northern Europe have an equally characteristic layer beneath the gray layer consisting of brown material, heavier in texture than the overlying gray layer. This layer must be considered characteristic of at least the true Podzols. This brown material consists primarily of organic matter but contains other constituents, especially alumina and iron oxide.

In 1924, Frosterus published a paper on the soils of Finland (*6*), in which he differentiated them into Eisen-Podzols and Humus-Podzols. In both kinds of soils the surface horizons are gray, but in the former group the layer of accumulation, or B horizon, contains a high percentage of iron oxide, compared with that in the gray surface layer, or A horizon, whereas in the latter soils the material in the B horizon consists mainly of organic matter and alumina. In the discussion of Podzols and Podzolic soils by Stremme and Aarnio, both kinds of Podzols are represented, but the Iron-Podzols seem to dominate.

In the course of time the Podzols and Podzolic soils have gradually developed into soils definitely differentiated by the processes by which they were developed into 2-horizon soils, leaving the underlying parent material out of consideration, consisting of a light-colored surface soil, or A horizon, which is also relatively light in texture when compared with the underlying, or B, horizon and a deeper colored, brownish, yellowish, or reddish B horizon, heavier in texture than the A horizon. The A horizon has been further defined as the horizon of eluviation, or the horizon from which material has been removed, and the B horizon as a horizon of illuviation, or one to which material has been added. The latter has been generally described as a horizon of accumulation, the material removed from the A horizon having been accumulated in B. This material consists either of alumina, iron oxide, or organic matter, occurring singly, two together, or all three together.

It seems to have been generally agreed that true Podzols should be defined as soils in which the A horizon is definitely gray and organic matter has been accumulated in the B horizon. It is universally agreed also that Podzols and Podzolic soils are developed only under the influence of a humid climate and occur most abundantly in forest-covered regions, but are not confined to them. The A horizon, especially the grayest part, or the A_2 subhorizon, reacts acid. This is usually true also for the whole profile, regardless of the character of the material from which the soil has developed.

Up to within the last few years, the characteristics of the Podzols and Podzolic soils have been discovered through studies carried on in the field, with very little assistance from the laboratory. During the second decade of this century, Gedroiz began effective work in the study, by chemical means, of the characteristics of the great soil types, and during the last 10 years highly important work has been done in the United States by a number of pedological chemists working on colloid material from soils. This work will be briefly referred to in another place.

Table 147 shows, like the chemical composition tables, that in both the Becket fine sandy loam and in the colloid from it, both alumina and iron oxide, in proportion to silica, have been lost during progress of soil development from the A_2 horizon. Assuming no shift of silica from one horizon to another and no greater total loss of this constituent from one horizon than from another, the number of molecules of alumina per molecule of silica is about 50 per cent less in horizon A than in horizon C. The number of molecules of iron oxide on the other hand in horizon A_2 per molecule of silica is only about half of that in horizon C. The proportional loss of iron oxide from A_2 has been much greater than that of alumina.

In horizon B_1 the ratios of both alumina and iron oxide are smaller than in either A_2 or C, showing a higher percentage of both constituents than in the original material and, therefore, an accumulation, on the basis of the same assumptions regarding silica as in the previous case, of both constituents, but the proportional gain in B has been much less than the loss in A. In alumina the gain has been less than 10 per cent and in iron oxide about 30 per cent.

In the colloid, the loss of alumina in A_2 is almost exactly the same as in the whole soil, but of iron oxide it is much greater.

The gain of alumina in B_1 is slightly higher than in the whole soil. The iron oxide proportion to silica, has been doubled. The ba ratios are in every case higher in A_2 than in B_1.

TABLE 147.—*Molecular ratios and pH values of selected Podzols*[1]

Soil type and sample No.	Horizon	Location	Ratios sa	sf	fa	ba	pH
Becket fine sandy loam:							
35888	A_2	Washington, Mass.	20.5	131.2	0.16	0.722	3.70
35889	B_1		12.3	46.3	.26	.585	3.90
35891	C		13.2	65.5	.20	.523	4.50
Becket fine sandy loam (colloid):							
35888	A_2	do	3.8	18.3	.17	.190	------
35889	B_1		1.9	1.6	1.19	.140	------
35891	C		2.1	3.2	.27	.190	------
Ontonagon silt loam:							
301606	A_2	Union Bay, Mich.	18.6	119.6	.15	------	4.32
301607	B		12.3	58.5	.22	------	4.59
301608	C		9.0	39.7	.22	------	5.30
Hibbing loam:							
28814	A_2	Hibbing, Minn.	13.9	113.2	.12	.933	4.17
28815	B		10.7	55.8	.19	.794	4.47
28817	C_2		6.9	25.0	.27	.572	4.35
Dekalb stony loam:							
28763	A_2	Lycoming County, Pa.	16.7	87.5	.19	------	4.29
28764	B_1		8.0	28.5	.27	------	4.50
28766	C		5.7	26.0	.21	------	4.72
Caribou loam:							
	A_2	Aroostook County, Me.	14.0	187.6	.07	.394	------
	B		8.5	32.9	.25	.315	------
	C_2		7.8	30.7	.25	.358	------

[1] pH determinations by E. H. Bailey, Bureau of Chemistry and Soils.

In every case these ratios show that these soils conform in the relation of the A and the B horizons to the general conception of the Podzols.

The general conception has, however, at least by implication if not explicitly, set forth that alumina and iron oxide or alumina or iron oxide, have been accumulated in B in all Podzols. Accumulation of one or both of these constituents in this

[22] GLINKA, K. D. THE GREAT SOIL GROUPS OF THE WORLD AND THEIR DEVELOPMENT. 235 p. Ann Arbor, Mich. 1927. [Mimeographed.]

horizon would reduce the silica-alumina ratio of one or both of these constituents in the B horizon to a value lower than the corresponding ratio in horizon C.

In none of the soils, other than the Becket, is this ratio in B smaller than in C but is, in every case, larger, showing not merely that no accumulation of alumina has taken place in horizon B but that an actual loss has been suffered.

The fa ratios do not indicate a uniform relationship of iron oxide to alumina among these soils. In Becket fine sandy loam and its colloid, iron oxide has accumulated more than has alumina, a fact shown by the other ratios. In Hibbing loam, iron oxide has accumulated more than alumina, assuming that the parent materials were originally uniform, in DeKalb stony loam, less, and in the other two the ratios in B and C are essentially equal.

Dr. H. G. Byers, the chief of the Division of Soil Chemistry and Physics of the Bureau of Chemistry and Soils, states that among the more than 20 Podzols of which colloids have been investigated in his division during the last few years a few have smaller sa and sf ratios in B than in C.

On the basis of the evidence contained in the analyses available within the United States, accumulation of alumina or iron oxide in the B horizon of the Podzols, over that in horizon C, measured in both cases by comparison with silica in the same horizons, may or may not have taken place.

The tables of complete chemical analyses of the Podzols show in every case a higher percentage of organic matter (nitrogen) in the B horizon than in A_2. Such an accumulation of organic matter in horizon B constitutes the ortstein, when indurated, and the orterde or ortsand when not indurated. Though this accumulation of organic matter is generally regarded as an unmistakable evidence of the activity of the podzolic process, large areas of soils in central Russia and in western Europe, in which no such accumulation has taken place, are designated as Podzolic. Reference has already been given above to the Humus-Podzol and Eisen-Podzol, defined by Frosterus in Finland, in the latter of which organic-matter accumulation does not exist or, if it does, to a very slight extent. In each of these soils the sa and sf ratios in A are higher than in C.

TABLE 148.—*Molecular ratios and pH values of selected soils from the Gray-Brown Podzolic group*

Soil type and sample No.	Horizon	Location	Molecular ratios				pH [1]
			sa	sf	fa	ba	
Sassafras sandy loam:							
29408	A_2		32.3	215.5	0.15	0.45	4.87
29409	B	Cabin Creek, Md.	13.0	94.9	.13	.40	4.87
29410	C		16.3	96.6	.17	.50	4.87
Sassafras sandy loam:							
29419	A		23.3	131.2	.18	.53	4.98
29420	B	Atlantic, Va.	15.0	67.0	.22	.32	5.15
29421	C		23.5	184.4	.13	.63	5.33
Sassafras sandy loam:							
29423	A_2		52.6	82.0	.17	.50	5.13
29424	B	Temperanceville, Va.	40.6	63.3	.24	.34	4.79
29425	C		45.4	70.7	.19	.37	4.79
Collington loam:							
29678	A_2		32.0	80.0	.77	.56	4.62
29679	B	Prince Georges County, Md.	25.4	22.0	1.16	.81	4.62
29680	C_1		52.3	17.0	3.10	1.48	4.62
Colts Neck sandy loam:							
29457	A		48.0	35.3	1.35	.54	4.62
29459	B_2	Red Valley, N. J.	26.1	13.7	1.90	.60	5.47
29460	C		25.9	17.7	1.45	.56	5.15
Chester loam:							
	A		11.5	47.5	.24	------	4.85
	B	Lee Heights, Va.	6.1	25.2	.26	------	4.85
	C		6.7	25.2	.26	------	5.25
Nason loam:							
35074	A		21.0	81.4	.26	.26	4.49
35075	B	Scuffletown, Va.	3.6	10.6	.35	.07	5.49
35076	C		6.2	23.4	.26	.16	5.49
Maury silt loam:							
28500	A_2		14.5	57.4	.32	------	6.49
28501	B	Ashwood, Tenn.	10.5	45.2	.23	------	6.15
28502	C		9.2	32.8	.28	------	5.89
Ontario silt loam:							
163220	A		13.8	59.2	.23	.40	6.62
163221	B	Lansingville, N. Y.	11.6	48.0	.23	.46	6.62
163222	C		11.9	53.8	.22	2.36	8.27
Gloucester fine sandy loam:							
1307137	A_2		11.7	49.4	.24	.61	4.79
1307138	B	Hinsdale, Mass.	11.4	59.7	.19	.60	4.96
1307140	C_2		12.0	71.9	.16	1.02	5.22
Miami silt loam:							
284020	A_2		13.3	64.6	.20	.53	5.13
284022	B_1	Hancock County, Ind.	8.4	31.1	.27	.39	5.18
284024	C		9.5	37.9	.25	3.29	8.26
Miami silt loam:							
283703	A_2		16.9	81.8	.20	.57	4.82
283705	B_2	Wayne County, Ind.	8.6	29.8	.29	.42	5.00
283707	C_2		11.5	49.9	.23	6.53	8.68
Miami silty clay loam:							
272303	A_2		12.1	49.2	.24	------	4.49
272306	B	Fayette, Ohio	6.8	22.2	.30	------	6.69
272309	C		6.8	24.7	.27	------	8.12
Miami silt loam:							
28527	A_2		14.3	75.0	.19	------	5.23
28528	B	Westport, Ind.	9.5	41.7	.23	------	6.57
28529	C		9.8	34.7	.28	------	7.85
Crosby silt loam:							
283760	A_3		12.3	41.5	.26	.48	6.15
283762	B_1	Wayne County, Ind.	8.1	35.6	.22	.36	6.10
283764	C		11.1	41.3	.26	3.69	8.25
Bethel silt loam:							
284026	A_2		13.7	64.6	.21	.54	6.00
284028	B	Westland, Ind.	6.8	27.8	.24	.43	6.75
284029	C		6.9	28.1	.24	1.17	7.70
Clinton silt loam:							
336425	A_2		13.4	74.3	.18	.57	5.67
336426	B	Amber, Iowa	10.3	43.4	.24	.44	5.22
336427	C		12.3	61.9	.20	1.67	8.19
Clyde silty clay loam:							
282207	A		7.6	34.6	.22	------	6.17
282208	B	Wells County, Ind.	7.7	32.3	.24	------	6.69
282209	C		7.6	33.4	.23	------	6.84

[1] pH determinations by E. H. Bailey.

Table 148 contains the same ratios as those computed for the Podzols, for 17 soils of the Gray-Brown Podzolic group, as the latter has been defined in this ATLAS. It includes also the ratios for one other soil occurring within the general Gray-Brown Podzolic region, Clyde silty clay loam, a dark-colored soil in which normal development has been prevented by ground water which has stood at or near the surface. It was introduced here to show the uniformity of its chemical profile features from the surface downward.

The sa ratio is uniformly higher in the A or A_2 than in the B horizon in all the normally developed soils. That development has attained a more advanced stage in some than in others is evident. In Gloucester fine sandy loam, for example, the ratio for horizon A_2 is 11.7 and that for B is 11.4. The chemical features of this soil as well as the well-known field characteristics show that development has just begun. This soil is confined to New England, where the material is comparatively coarse as well as sandy, was accumulated at a relatively late geological date, and the processes of rock decomposition because of the cool climate proceeds slowly. On the other hand, in Nason loam from Virginia, the sa ratio for horizon A is 21 and for B is 3.6. Development has reached an advanced stage in this soil.

The sf ratios are higher in A or A_2 than in B in each of the maturely developed soils except Gloucester fine sandy loam. In general the difference between the ratios in these horizons is greater than between the sa ratios for the same horizons. The maximum difference is found in the Nason loam of Virginia, the soil showing the maximum difference between the sa ratios of these horizons. The differences in the cases of Maury silt loam and Ontario silt loam are small, the latter being a young soil developing from relatively heavy, highly calcareous glacial drift, and the former, a soil from which a considerable part of the surface soil, or A horizon, has been removed by erosion, the A horizon in the sample collected being only partly developed from what seems to consist of a former B horizon.

The fa ratios show that the apparent accumulation of iron oxide in horizon B, compared with horizon A, is greater than of alumina. The differences, however, between the ratios in the two horizons are not great, but the iron oxide, under the conditions existing in the Gray-Brown Podzolic region, is removed from A to a greater extent than alumina in the larger number of the soils.

In Maury silt loam, the evidences of a derivation of the existing ill-defined A horizon from a former B, suggested by the sa and sf ratios, are confirmed by the fa ratio. Crosby silt loam is not a normally developed soil, and Sassafras sandy loam at Cabin Creek, Md., is very sandy but is otherwise a normal soil.

The ba ratios are generally higher in the A than in the B horizon.

The relationships of the B and C horizons, as brought out by the several ratios, are similar to those in the Becket soils. The sa ratios for the B horizons are smaller in all but 3 of the 17 normally developing soils. In two of the three exceptions they are essentially identical, and in the third the difference is very small. In general, the amount by weight relative to silica is higher in horizon B than in C. The difference between the amount in B and that in C is much less, however, than that between B and A or A_2. There has, therefore, been some accumulation of alumina in horizon B, but this is much less than that lost from A or A_2.

The sf ratios for the B and C horizons are dominantly like the sa ratios. Of the 17 normally developing soils, the ratios for the B horizon are smaller than those for the C horizon in 14; it is the same in both horizons in 2, and is larger in 1 only. Iron oxide, like alumina, has been accumulated in horizon B but in much less quantity than it has been removed from A.

The fa ratios are equally definite in showing what has taken place. In 13 of the soils, the ratio in B is higher than in C. It is evident that iron oxide in by far the greater number of these soils has increased to a greater extent than has alumina.

The ba ratios for the A horizon are generally higher than those for the B, though in the Collington loam this ratio is smaller in the A. That for the C horizon depends on the character of the parent material. In cases where that is calcareous glacial drift, it is high. In other cases it is lower, though rarely lower than in the B.

The relationships of silica, iron oxide, and alumina in the A, B, and C horizons of the soils of the Gray-Brown Podzolic group are entirely different from those in the greater number of the Podzols. In the latter, except those of Becket fine sandy loam, these ratios show that neither iron oxide nor alumina have accumulated in B, since they are higher for that horizon than for C. Excepting Becket fine sandy loam, iron oxide and alumina have been lost from both the A and B horizons, but the loss from A has been greater than that from B.

In the Gray-Brown Podzolic soils the ratios show, in by far the greater number of cases, well-defined accumulations of both iron oxide and alumina in B. As explained on a preceding page, no accumulation of organic matter has taken place. These are well-drained normally developed soils, and, although they show some accumulation of alumina, the amount is much smaller proportionally to the amount present in the soil than of iron oxide. These soils, therefore, seem to be essentially like Frosterus' Iron Podzol.

In each of these soils, except Collington loam and Gloucester fine sandy loam, the sa ratio in A is higher than in C. Collington loam has developed from glauconitic deposits which differ, from place to place, in the richness of the glauconite content. In the spot where this sample was collected, the content was high. The content of alumina in the parent material, therefore, is very low and of iron oxide is high. Gloucester fine sandy loam is an immaturely developed soil, and the content of coarse material in which quartz is an important constituent is high in the C horizon.

The sf ratio is higher and usually much higher in horizon A than in horizon C in each of the soils of this group, except Sassafras sandy loam and Gloucester fine sandy loam. In both cases this is owing to a high content of quartz in horizon C.

The several ratios in the A, B, and C horizons of 38 soils assigned in the work of the Soil Survey to the group of Red and Yellow soils are shown in table 149. The colloid of three soils is included, reducing the number of separate soils to 35. In every soil of the 35 and in the colloid of two of these, the sa ratio of the A horizon is larger than that of the B. Those of the remaining colloid are essentially equal in both the A and B horizons. Among the 35 soils, the range in texture of the surface soil is from sand to clay. In the very sandy soils, such as Norfolk sandy loam from Gaston, S. C., the difference is very wide. In the colloid it is small. In general, however, the differences are larger than in the soils of either of the two groups already described.

TABLE 149.—*Molecular ratios and pH values of selected soils from the Red and Yellow soils group*

Soil type and sample no.	Horizon	Location	Molecular ratios				pH
			sa	sf	fa	ba	
Norfolk sandy loam:							
34737	A_2		100.9	218.5	0.461	0.64	5.05
34738	B	Bennettsville, S. C.	17.3	85.3	.202	.10	5.05
34739	C		19.1	107.6	.177	.11	4.96
Norfolk sandy loam:							
29185	A_2		23.8	412.7	.576	------	5.52
29186	B	Gaston, S. C.	80.0	227.1	.351	------	5.22
29187	C		21.3	120.8	.176	------	4.63
Marlboro fine sandy loam:							
32613	A_2		31.9	136.9	.233	------	4.63
32614	B	Wilson, N. C.	8.9	35.4	.249	------	4.63
32615	C		8.5	34.4	.247	------	4.63
Norfolk sandy loam:							
30226	A_2		30.6	114.6	.266	------	5.57
30228	B_2	Raiford, Ga.	12.0	53.1	.226	------	5.13
30229	C_1		13.0	66.2	.200	------	5.35
Norfolk sand:							
30220	A_2		138.7	998.3	.138	------	5.47
30223	B	Greenwood, Ga.	27.5	143.6	.191	------	5.47
30224	C		36.7	153.5	.238	------	5.13
Norfolk fine sandy loam:							
29128	A_2		108.3	168.8	.323	------	4.87
29130	B_2	Thomasville, Ga.	7.2	11.3	.642	------	5.09
29131	C		8.2	57.4	.142	------	5.13
Norfolk sandy loam:							
32334	A_2		33.6	416.6	.080	------	4.89
32335-6	B_1	Dothan, Ala.	16.2	198.5	.080	------	4.89
32338	C		11.9	174.3	.068	------	4.94
Tifton fine sandy loam:							
32301	A_2		44.6	265.4	.167	------	5.00
32302	B_1	Carnegie, Ga.	5.4	31.0	.174	------	5.00
32304	C		6.6	23.2	.285	------	5.10

TABLE 149.—*Molecular ratios and pH values of selected soils from the Red and Yellow soils group*—Continued

Soil type and sample no.	Horizon	Location	Molecular ratios				pH
			sa	sf	fa	ba	
Tifton sandy loam:							
32341	A_2	Ocilla, Ga.	11.9	60.1	.194	.036	5.10
32343	B		3.5	13.9	.251	.045	5.15
32344	C		5.4	18.4	.295	.064	5.15
Tifton sandy loam:							
30232	A_2	Meigs, Ga.	57.0	174.5	.326		5.57
30234	B_2		10.7	45.5	.234		4.96
30235	C		11.2	35.3	.317		4.96
Greenville sandy loam:							
28902	A	Evergreen, Ala.	41.0	152.7	.267	.290	5.13
28903	B		19.1	50.5	.377	.088	5.13
28904	C_1		24.0	19.1	1.290	.130	5.35
Greenville sandy loam:							
258507	A_2	Quitman, Ga.	23.4	67.5	.346	.167	5.36
258508	B_1		4.6	14.0	.328	.054	4.99
258510	C_1		11.4	7.9	1.430	.149	4.79
Greenville sandy loam:							
28560	A_2	Tallahassee, Fla.	31.2	122.6	.254		5.37
28561	B		20.7	85.6	.242		4.79
28562	C		17.5	94.7	.184		5.05
Grenada silt loam:							
425002	A_1	Rankin County, Miss.	22.5	120.9	.185	.471	4.90
425003	B_1		10.3	39.4	.260	.274	4.69
425005	C		23.6	111.3	.211	.241	4.79
Grenada silt loam:							
28006	A_1	Grenada, Miss.	15.0	52.9	.282	.522	
28007	B_1		11.9	41.6	.286	.455	
28009	C		13.4	43.7	.306	.738	
Decatur silt loam:							
30250	A_3	Childersburg, Ala.	19.2	64.9	.294		5.22
30252	B_1		6.7	23.0	.290		5.22
30253	C_1		3.4	15.0	.228		5.47
Nacogdoches fine sandy loam:							
447094	A	Nacogdoches County, Tex.	43.3	27.6	1.560		6.15
33410	B_1		2.7	4.3	.613		4.75
447099	C		5.0	8.6	.575		7.50
Cecil fine sandy loam:							
34996	A	Rutherfordton, N. C.	7.0	35.7	.197	.244	4.79
34997	B_1		2.8	11.0	.259	.106	5.63
34998	C_1		3.2	12.6	.256		5.63
34999	C_2		4.3	33.2	.129	.680	5.80
Cecil fine sandy loam (colloid):							
34996	A	do	1.6	8.1	.195	.040	
34997	B_1		1.5	5.9	.251	.022	
34998	C_1		1.2	7.0	.176	.024	
Cecil clay loam:							
236505	A_2	Green Hill, N. C.	4.9	24.2	.203	.155	4.79
236507–08	B_2		2.7	10.4	.262	.092	5.47
236509	C		3.5	24.5	.144	.458	5.98
Cecil fine sandy loam:							
236902–03	A_2	Brooks Cross Roads, Yadkin County, N. C.	26.3	165.5	.158	.809	5.02
236906	B_2		1.6	8.1	.202	.066	5.13
236907	C		3.1	15.6	.196	.201	5.13
Cecil sandy loam:							
32366	A_2	Anderson County, S. C.	22.3	146.0	.158	.323	5.15
32367–8	B		3.4	15.0	.231	.106	5.15
32370–71–72	C_2		6.9	48.0	.144	.278	5.23
Cecil fine sandy loam:							
30263	A_1	Decatur, Ga.	20.8	61.7	.336		5.25
30266	B_1		5.9	23.9	.246		5.25
30269	C_1		5.0	22.3	.248		5.53
Cecil fine sandy loam:							
28911	A	Lula, Ga.	34.0	193.8	.175	.2560	4.69
28912	B		3.9	27.1	.144	.0770	5.13
28915	C_3		6.4	63.2	.101	.2250	5.30
Cecil sandy loam:							
28917	A	Mount Airy, Ga.	20.4	85.4	.239	.1006	4.62
28918	B		4.5	16.0	.283	.0403	4.87
28919	C_1		8.6	47.3	.182	.0661	5.05
Cecil clay loam:							
32352	A	Lanett, Ala.	10.1	18.8	.538	.1600	5.47
32353	B_1		4.3	12.2	.351	.0900	5.47
32357	C_2		5.3	16.0	.334	.1900	5.47
Cecil clay loam (colloid):							
32352	A	Lanett, Ala.	1.6	7.2	.229	.0260	
32353	B_1		1.7	5.9	.282	.0170	
32354	B_2		1.8	6.4	.278	.0210	
Georgeville silty clay loam:							
236715	A	Henrico, N. C.	7.8	36.1	.216	.1140	4.79
236716	B_1		3.5	17.2	.205	.1010	4.79
236718	C		5.2	27.0	.193	.2760	5.05
Georgeville silt loam:							
32617	A_2	Thelma, N. C.	16.1	65.8	.243	.4720	4.63
32618	B		3.9	16.1	.242	.0980	4.37
32620	C_2		7.1	37.2	.191	.2980	5.52
Durham fine sandy loam:							
32382	A_2	Reidsville, N. C.	13.6	130.5	.104	.8780	4.98
32383	B_1		4.8	37.9	.126	.2720	5.30
32386–87–88	C		8.3	92.6	.900	.6950	4.88
Durham fine sandy loam:							
30254	A	Stone Mountain, Ga.	12.4	206.8	.060		5.17
30258	B		6.1	88.9	.070		5.17
30261	C_2		8.2	212.9	.040		5.62
Appling sandy loam:							
236516	A_2	Sandymush, N. C.	28.7	172.8	.166	.7570	5.05
236518	B_2		2.9	21.4	.135	.1500	5.30
236520	C_2		6.0	50.3	.116	.2550	4.79
Appling sandy loam:							
257802	A_2	Milner, Ga.	25.8	269.9	.095		4.79
257804	B_2		4.4	27.2	.164		5.05
257805	C		4.5	40.9	.111		4.80
Porters loam:							
35000	A_1	Chimney Rock, N. C.	10.6	86.3	.122	.7090	4.65
35001	B		4.8	32.5	.149	.2290	5.15
35001B	C_2		8.5	70.0	.122	.9100	5.15
Davidson clay loam:							
	A	Greensboro, N. C.	9.3	29.5	.314	.1600	6.4
	B_2		3.7	9.0	.413	.0370	4.5
	C		4.3	10.4	.408	.0600	4.4
Davidson clay loam (colloid):							
	A	do	1.8	7.4	.247	.0570	
	B_2		2.0	4.5	.448	.0280	
	C		2.0	4.8	.433	.0360	
Iredell loam:							
236921	A	West Bend, N. C.	11.6	13.4	.859	.6800	6.40
236922	B		3.1	11.1	.283	.2230	6.09
236923	C		3.9	11.8	.340	.7870	6.82
Iredell loam:							
	A_2	Greensboro, N. C.	8.7	3.1	.669		6.9
	B		3.7	9.1	.411		6.7
	C		4.0	9.8	.406		6.7

The sf ratio is larger in horizon A than in B in every soil except Iredell loam from Greensboro, N. C. The differences also, between these ratios are generally wide, that for the A horizon being in general larger than the sa ratios for the same horizon. In every case among the mature or approximately mature soils, actual removal of iron oxide from horizon A has taken place. The ratio of iron oxide to alumina (fa) in the A and B horizon does not point so consistently to one conclusion as do those of silica to alumina or to iron oxide. In 14 soils and colloids the ratio of iron oxide to alumina in A is greater than in B, in 18 it is smaller in A than in B, and in 4 it is essentially the same in both. There has been, therefore, no uniform ratio of iron oxide to alumina in the material shifted from the A horizon in these soils. No attempt has been made to correlate the differences in these proportions with the stage of profile development. In general, as in the soils of the groups previously discussed, the ba ratio in A is higher than in B.

The several ratios in the B and C horizons point to the same conclusion regarding the shifting of materials as in the previously discussed groups. Of the 35 soils in the table, the sa ratios in the B horizon of 27 are smaller than in horizon C. In 6 soils they are larger, and in 1 they are essentially the same in both horizons. In the 6 soils in which this ratio is larger in B than in C, the differences are small, except in a very sandy type of the Norfolk series. If the soils can be accepted as representative of those in the Red and Yellow group, the evidence is clear that accumulation of alumina has taken place in horizon B.

The sf ratios in horizon B in 26 of the 35 soils are smaller than in horizon C. In 8 soils the sf ratio is larger and in 1 it is essentially the same. Exactly the same story is told by these ratios as by the sa ratios. When compared with the silica, iron oixde has accumulated in the B horizon of these soils.

The fa ratio in 22 of the 35 soils is larger in horizon B than in C, in 8 it is smaller, and in 5 it is essentially the same. It is apparent, therefore, that the gain of iron oxide from B has been greater than of alumina. The sa ratio in the A horizon in 18 of these soils is smaller than in B, in 14 it is larger, and in 4 essentially the same.

Iron oxide has suffered removal from A to a greater extent than from B. The ba ratios, as in the soils of the other groups, are generally larger in A than in B and, in many cases in these soils, than in C.

The relationships of iron oxide, silica, and alumina, as well as the direction in which shifting of these compounds has taken place in the course of soil development, is the same in the Gray-Brown Podzolic soils and the Red and Yellow soils. The data are not sufficient for a conclusion regarding the Podzols. If these relationships and this direction in which shifting has taken place can be accepted as the basis for the definition of Podzolic soils, it is clear that two of these soil groups may be defined as Podzolic. If the term Podzolic can be applied to the Gray-Brown soils there seems to be no sufficient reason for not applying it to the Red and Yellow soils. It is apparent that these soil groups could properly be designated as Podzols, Gray-Brown Podzolic soils, and Red and Yellow Podzolic soils.

No attempt can be made here to discuss the processes by which podzolization is brought about and to compare them with the processes operating in the development of the other great soil groups. An attempt has been made to make a clear statement of what has taken place and to compare this with the general opinions regarding what takes place in Podzol formation. If the removal of alumina and iron oxide from the A horizon and the reduction of the content of those constituents in this horizon well below that in horizon C, which, presumably shows the content of these constituents in what is now horizon A before the latter was developed, constitute podzolization, these soils are Podzolic. If the accumulation of iron oxide and alumina or either of these constituents in the B horizon to a content higher than in horizon C is a necessary result of podzolization, these soils are Podzolic.

The work of Anderson and Byers, and of Brown and Byers, on the colloid material from Podzols, have shown that in the Podzol process a fractionation of the colloid takes place. Whether in the future, this process will be accepted as characteristic for the soils of this group, can not now be determined.

The assembled ratios for seven soils belonging in the group designated in this report as Prairie soils are shown in Table 150. Five of these soils are what are regarded in the United States as normal Prairie soils, and two, Summit clay loam and Cherokee silt loam, as not normal.

TABLE 150.—*Molecular ratios and pH values of selected soils from the Prairie-soils group*

Soil type and sample No.	Horizon	Location	Molecular ratios				pH
			sa	sf	fa	ba	
Carrington silt loam:							
375503	1	Butler County, Nebr.	11.50	53.90	0.213	0.517	5.92
375504	2		10.20	48.30	.210	.455	6.49
375505-06	3		9.90	42.20	.234	.454	7.60
Shelby loam:							
336309	1	Fremont County, Iowa	12.70	51.70	.247	.679	5.80
336310	2		10.60	48.50	.218	.586	6.33
336311	3		9.60	40.60	.237	1.450	8.02
Marshall silt loam:							
336301	1	Fremont County, Iowa	10.30	61.30	.167	.507	6.00
336302	2		9.70	48.70	.198	.446	6.09
336304	4		10.12	60.26	.167	.603	7.52
Tama silt loam:							
34777	1	Newton, Iowa	10.50	49.10	.213	.482	5.94
34779	3		8.30	36.40	.227	.367	5.55
34781	4		8.70	37.40	.232	.390	5.09
Summit clay:							
29910	1	Wellington, Kans.	10.60	53.30	.198		6.32
29911	2		11.90	56.80	.210		5.98
29913	4		9.80	48.00	.204		7.87
Summit clay loam:							
29846	1	Belleville, Kans.	10.80	67.90	.159		6.35
29848	3		7.60	36.70	.208		6.90
29849	4		8.60	47.10	.182		8.17
Cherokee silt loam:							
27891	2	Labette County, Kans.	24.80	78.30	.382		5.30
27892	3		7.80	39.70	.197		5.80
27893	4		6.90	37.00	.185		6.30

The successive layers or horizons in the soil profile from the surface downward are designated by numbers rather than by letters, since they do not have characteristics identical with those of the Podzolic soils.

In each soil, except Summit clay, the sa ratio for the surface soil is higher than that for any lower horizon or layer. The differences between this ratio for the first and second layers shown in the table are, however, small in the first four soils, and for the sixth, or what are considered normal Prairie soils. The maximum difference, leaving Cherokee silt loam out of consideration, is only 3.2, a figure much smaller than in any of the groups previously described. In Summit clay the ratio in the surface soil is smaller than in the underlying horizon.

In Cherokee silt loam the relative ratios are similar to those in the Podzolic soils. In this soil, layer 3 consists of tough heavy clay, and layer 2 of a light-gray silty structureless layer very much like the A_2 horizon of the Podzolic soils. Its gray color has been brought about by the water logging caused by the very slow penetrability of layer 3. The iron oxide in this layer has not been merely reduced but has been removed, and the alumina has been subjected to removal also.

The sf ratio is larger in the first, or highest, layer shown in the tables, being the surface horizon in all cases, except in the second and seventh soils, than in the layer underlying it, except again in the fifth. The differences between the sf ratios in these two horizons are greater than are the sa ratios ranging up to 31 in Summit clay loam but down to 3 in Shelby loam.

The ba ratio in the four soils, for which it has been computed, is invariably higher in the highest layer represented than in the underlying layer.

The sa ratios in layer 3, which may be considered the parent material, are lower in four of the seven soils than in layer 2. The differences are small, and in the three cases in which they are higher, the differences are very small.

The sf ratios also are lower in layer 3 in four of the soils than in layer 2 and higher in 3. Compared with the Gray-Brown or Red and Yellow soils, these differences are all small. The fa ratios are smaller in three of the soils and larger in four.

On the basis of the several ratios in these soils, and accepting these as indications of the activity of the podzolic process, it is evident that some podzolization has taken place in these soils, ranging from a mere beginning to well-defined but not strong evidence of its action, except in the case of Cherokee silt loam and less strongly in Summit clay loam.

THE PEDOCALS

The soils described up to this point have belonged to the Pedalfers, one of the two great soil groups, described on page 14, into which all soils of the United States have been divided. The two groups may be approximately designated as humid soils, the Pedalfers, and subhumid and arid soils, the Pedocals. The terms humid, subhumid, and arid, when applied to soils, are merely general designations without significance in scientific soil nomenclature. They are climatic terms that have been used in soil literature for many years merely as general terms, without exact meaning, before pedological terms had come into use.

The respective areas of distribution of the soils of these two groups in that part of the United States east of the Rocky Mountains are essentially continuous. Attention has been called to this fact on a preceding page and it is again referred to merely for emphasis. These areas are shown on the small outline map (fig. 1.) Within the Pedalfer area all the soils are either maturely developed Pedalfers; young soils whose characteristics are still imperfectly developed but such as have developed are Pedalfer characteristics; or soils in a still more primitive stage of development where, due to local conditions, their normal course of Pedalfer development has not yet begun but which, because of their association in identical environment with mature Pedalfers can not be considered as any other than potential Pedalfers.

Within the Pedocal area the same statement is true in general and practically in detail. The only area of Pedalfer soils within the Great Plains area of Pedocal soils consists of the Black Hills. In addition to the Great Plains area of Pedocals another large, approximately continuous area, but less continuous than the preceding, is that of the Great Basin, lying between the western foot of the Rocky Mountain belt, taken as a whole, and the eastern foot of the Pacific ranges. Within the Rocky Mountain and Pacific range belts both groups of soils occur in great numbers of areas ranging widely in size. The higher lying areas throughout the region are Pedalfers. In the Pacific northwest, in the Pacific coast ranges, and in the northern part of the Rocky Mountain belt considerable areas of Pedalfers lie at moderate elevations. Elsewhere the lower areas are mainly covered by Pedocals.

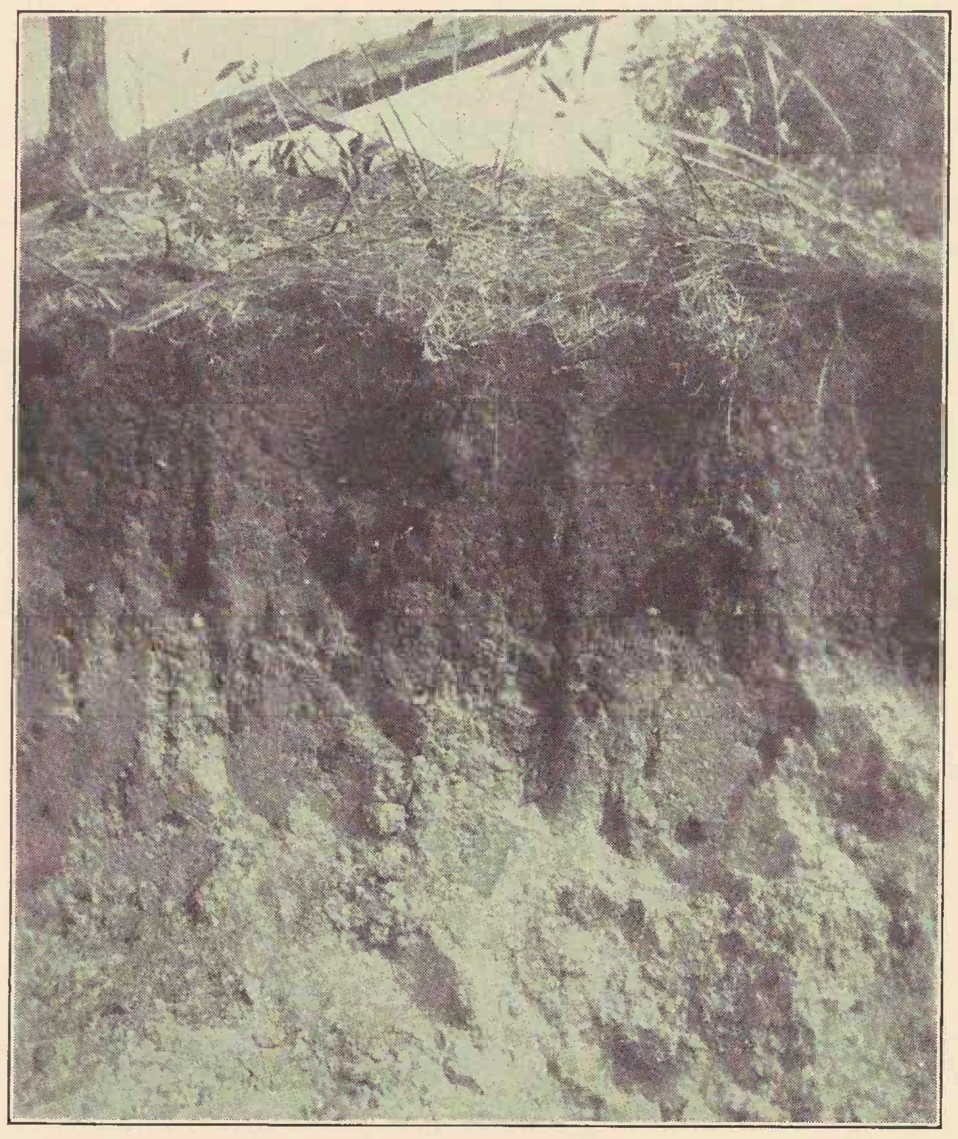


FIGURE 35.—Profile of Barnes silt loam (a Chernozem), near Huron, S. Dak.

The soils of this great group have been differentiated on the basis of their soil characteristics only, and without reference to climate. It is well known, of course, that climate has been an important factor in the determination of those characteristics, the natural vegetation being the other of the two great dynamic factors, but the soils have not been differentiated on the theoretical basis of having been developed by factors of any kind but on the basis of actual characteristics.

The basis of differentiation of the two great groups has already been described (p. 14), this being the presence in the Pedocals of a zone of carbonate accumulation and its absence in the Pedalfers. Since this zone is one of accumulation and is therefore a product of development it is evident that it can not exist in the soil until at least a considerable advance in stage of development has been attained. The differentiation, therefore, of the soils of the United States into these two great groups, is a differentiation based entirely on the characteristics of the mature soils and not on the characteristics of undeveloped or immature soils. Immature soils associated with the mature soils will in time develop the characteristics of mature soils. They are grouped therefore with the soils which contain the characteristics toward which the immature soils are developing, but the definition of the group is based on the characteristics of mature soils only.

The Pedocals have been differentiated into four subgroups designated, respectively, as the Chernozem, Dark-Brown, Brown, and Gray groups according to the color of the surface layer to a depth ranging from 6 to 15 inches. The soils of each group occupy a series of north-south belts succeeding each other from east to west, the first two extending practically unbroken from the northern to the southern boundaries of the United States. The other two occupy less continuous belts (pl. 1).

It will be remembered that the soils of the several groups of Pedalfers, Podzols, Gray-Brown Podzolic, and others occupy ill-defined east-west belts.

The soils of the Pedocal group range in color from black to gray, the subgroup with the blackest soils occupying the most easterly belt, that with the gray soils the most westerly. The two other subgroups occupy intermediate positions and have soils of intermediate colors. The soils of any given belt are lighter in color than those of any belt east of it and darker than those of any belt west of it. The darkness of the soils is an expression of the density of grass cover under which they developed. This, in turn, other things being equal, is the result of rainfall, the higher rainfall supporting the most dense grass cover, the lowest the least. The Pedocal groups are distributed therefore in belts which correspond to the distribution of belts of rainfall, the westwardly decreasing soil color coinciding with westwardly decreasing rainfall. Each belt may be broken up into two stretches, a northern and a southern, corresponding to differences in temperature.

The differentiation of the Pedocals into groups based on the color of the surface horizon was established about half a century ago in Russia, on the basis of Russian conditions, but it is found that they correspond to conditions in the United States closely enough to warrant the establishment of the same general groups in both countries. Since the great belts in southeastern Europe run east and west and therefore parallel to lines of rainfall and temperature differences, and in this country north and south parallel to differences in rainfall but perpendicular to differences of temperature, it is evident that the groups in the respective countries can not fit exactly. It is apparent that only a relatively small part of the soils of the great groups as they are developed in the United States can be exactly identical with those of the great groups as they are developed in southeastern Europe.

THE CHERNOZEMS

The most easterly of the Pedocal belts is that of the Chernozems, a modified form of a Russian word meaning black earth. This is the belt containing the darkest colored soils. Westward, even within the belt and also beyond it, the soils become gradually lighter in color than along the eastern margin, corresponding to differences in rainfall and also, as a matter of mere observation, to differences in density of grass growth. All of these dark-colored soils, though not all of the Pedocals, are grassland soils, and as is the case with the Prairie soils, their dark color is caused by the accumulation of organic matter through the growth and decay of grasses. As explained by Shantz and Zon (*16*), the grasses of the United States are grouped into two great groups known as tall grasses and short grasses. The Prairie soils lie wholly within the tall-grass region. The greater part also of the Chernozem belt is in the tall-grass region, though the short grasses become dominant in the extreme western part of the belt, especially in Kansas and Texas, whereas the tall grasses, though of different species from those in the prairies, extend over practically all of the belt in the Dakotas.

All the belts or great soil groups of the Pedocals extend northward from the United States into Canada, and it is apparent that most of them extend southward into Mexico. Practically nothing, however, is known of their extension in the latter country. In the United States they occupy belts which extend almost due north and south, but in the Canadian northwest they assume a northwest-southeast course. Plate 2 shows the first and second Pedocal belts broken into two parts, a northern and a southern, and in addition to this the Chernozem belt is interrupted by the sand hills of Nebraska. The line between the two main parts runs across southern Kansas. On the large soil map (pl. 5, secs. 3, 6, and 11), on the other hand, each of these subgroups contains a number of series groups and units. From north to south the dominant series in the Chernozem belt, taken as a whole, consist of the Barnes soils in the Dakotas, the Moody and Holdrege soils in Nebraska, the Hays soils in Kansas, the Amarillo soils in northwestern Texas, the Valera soils in the Edwards Plateau of Texas, and the Victoria and Duval soils of southern Texas.

The Barnes soils are dominant within the Chernozem belt of the Dakotas (fig. 35) and extend northward into Canada. They are associated, however, with two other series groups, both of which are important. These are the Fargo and Williams soils. The Barnes soils are black, the black surface horizon ranging generally from about 12 to 15 inches in thickness. They are often popularly described as consisting of black soil to a depth of many feet. Except where materials washed from the surface soil have been locally accumulated, they never attain a thickness of as much as 3 feet and in few places are they more than 20 inches thick. This is not only true of the Barnes soils, but it is true of all the black soils of the United States, and especially true of the Prairie soils. Corresponding soils in south Russia, however, attain a thickness that persists over large areas, ranging from 4 to 6 feet.

In very few places do the Barnes soils show the development of granulation. This has been the cause of considerable surprise, since the soils in the same belt farther south are in most cases well granulated. The dominant soil type is loam or fine sandy loam. Because of the geologically recent period of accumulation of the glacial material from which they have developed, the Barnes soils are still young. Some granulation has been discovered in the heavy types, but as a whole the soils are not granular.

The surface horizon is underlain, as a rule, by a thin layer of brownish material of about the same texture as the dark-colored layer, and this layer, in turn, by the zone of calcium-carbonate accumulation. Highly calcareous glacial drift lies beneath the zone of calcium-carbonate accumulation, but above this zone effervescence in acid does not take place. The organic matter is saturated, however, and reaction is neutral. In characteristics of the dark-colored layer and the material immediately underlying it, the Barnes soils are essentially like the Clarion soils of the prairies. The two soils have developed from very similar parent material and on identical relief, but the Barnes soils have developed under a lower rainfall than the Clarion, and although the latter are underlain by highly calcareous material, this is the parent material and not part of a zone of carbonate accumulation. In the Barnes soils, however, a zone of carbonate accumulation is present above or at the top of the unleached parent material.

The Fargo soils, associated with the Barnes, occupy a strip along the eastern side of North Dakota and the western side of Minnesota. They occupy also small areas scattered throughout the area of Barnes soils all of which are too small to show on the large soil map. They are shown, however, on the detailed soil maps covering the various projects surveyed in North Dakota. The Fargo soils have developed from lake-laid material, the main area being developed from material accumulated in ancient glacial Lake Agassiz. The profile, where it has developed far enough for the determination of the general trend of development, is identical with that of the Barnes soils. In most cases very little profile development, other than the removal of the existing calcium carbonate from the surface soil to a depth of about 2 feet and the accumulation of organic matter, has taken place. In rare cases only does there seem to have developed a thick zone of lime accumulation, although accurate studies for the determination of such accumulation have not yet been made. In texture these soils are, as a rule, heavy and, since they occupy areas where the relief is practically flat, they have not been subjected to so much leaching as the Barnes soils. In certain localities also they have been subjected to the influence of small amounts of salts and have developed areas of Solonetz soils. These "alkali" soils are not salty in the sense that they contain enough readily soluble salts to interfere with the growth of plants, but they contain enough salts, presumably sodium carbonate, to cause the development of what is known as an alkali hardpan. The areas affected with hardpan are not large, and the hardpan has not been highly developed. It is a claypan rather than a hardpan.

The light-textured soils developed from material deposited in Lake Agassiz, mainly around the margin of the lake, have been mapped as members of the Bearden series,

mainly because of good drainage which is owing mainly to their occurrence on slight ridges and partly to their relatively coarse textures. In a few places these soils are underlain by material which is somewhat lighter in texture than the surface soil. The surface is smooth and has not the billowy relief like that on which the Barnes soils have developed, the latter soils being morainic, and the profile is normally well developed. In essential characteristics they are Barnes soils developed from comparatively light textured water-laid but well-drained materials.

West of the large area of Barnes soils in the Dakotas is a belt of soils mapped as members of the Williams series. These soils do not differ in essential characteristics from the Barnes soils except in the thinness of the surface soil or dark-colored horizon which is rarely more than 10 inches thick. The surface horizon is slightly lighter in color than that of the Barnes soils. In other respects the profile is identical with that of the Barnes soils.

The Barnes and Fargo soils extend across the international boundary northward and occupy large areas in the prairie provinces of Canada. Northward they seem to contain an increasing amount of organic matter.

The parent material of the Barnes soils in Canada is in general character identical with that in North and South Dakota, being highly calcareous glacial drift containing, especially in Canada, a considerable amount of gypsum. Many samples of soil were collected in the Great Plains region several years ago and subjected to chemical analyses, but very few of them included parent material. They were collected at a time when attention was directed to the zone of lime accumulation and especially the relation of this zone to the dark-colored surface horizon, and less attention was paid to the parent material. Later Canadian and Dakota samples of the Barnes series were collected, in which the horizons of the solum, as well as of the parent material, were included. Earlier studies in the Great Plains had clearly shown the presence of a zone of accumulation, but the actual quantitative determination of the percentage present in this zone and in the parent material also was not made until the summer of 1926, when Canadian samples were collected.

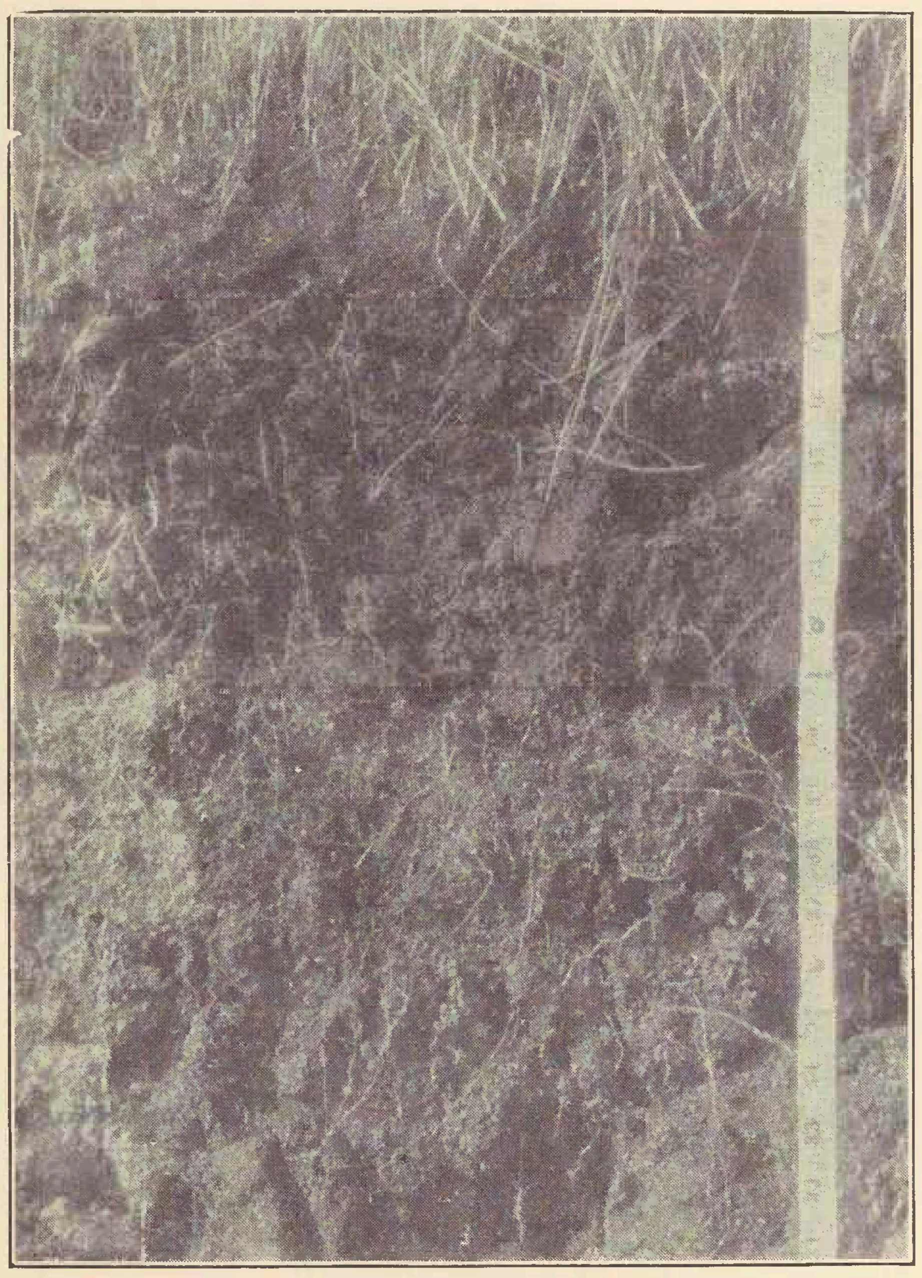


FIGURE 36.—Profile of Hastings silt loam near Sutton, Nebr., showing granular structure.

In northeastern Nebraska, extreme northwestern Iowa, and southeastern South Dakota, including also an area in the southwestern corner of Minnesota, the soils have developed from a thick bed of calcareous brown silt. This material seems to have accumulated by wind deposition and presumably was derived, at least in part, from the alluvial valley of the Missouri River. It is identified by geologists as loess. Some of the material may have come, and probably did come, from the sand-hill region of Nebraska, which lies immediately west of it. Since the latter is a region in which the sandy parent material has been blown up into dunes by the prevailing westerly wind, it is apparent that the finer material would be blown eastward and beyond where the sand is deposited and into the region of northeastern Nebraska. It is well within the range of possibility that the silty material in northeastern Nebraska has had a somewhat different immediate origin from that on the northern and eastern side of the Missouri River in South Dakota and Iowa, the latter being derived, in part at least, from the Missouri River flood plain. Although this may be true regarding the actual immediate source of this material, in fundamental character there can be no essential difference between them since materials on both sides of the river were derived from regions of the Great Plains where very little leaching has taken place.

The normally mature soils developed on this silty material have been identified as members of the Moody series. The profile is, in its fundamental features, identical with that of the Barnes soils but differs in having a somewhat lower percentage of organic matter and a lighter color in the surface soil. Along the eastern part of the belt there is a brown horizon between the dark-colored horizon and the zone of calcium-carbonate accumulation.

The lighter color of the Moody soils, as compared with the Barnes, is probably due to a number of causes, but the exact causes have not been determined. The region lies south of that in which the Barnes soils occur, and being warmer, other things being equal, the organic accumulation would not be so large. This statement is based on experience acquired in comparing soils in the northern part of the United States with those in the southern part in regions where conditions other than temperature are uniform or as nearly so as can be determined. The lower percentage of lime in the parent material of the Moody as compared with that of the Barnes soils is probably also a factor. It is probable that the very dark color of the Barnes soils is in part due to their derivation from very highly calcareous glacial drift, combined with their youth. They seem to be rendzinalike, to this extent at least, in their characteristics. The Moody soils, on the other hand, have developed from materials less highly calcareous than the Barnes, and the stage in which their characteristics were rendzinalike has already passed.

South of the east end of the sand-hill region and continuing as an extension of the silty material westward from the principal area of the Moody soils, is an area of soils mapped as Colby. It lies in the western part of the Chernozem belt where the rainfall is lower than in the eastern part and where, therefore, the growth of grass is not so dense. It lies also within a region that has been severely dissected by erosion. The surface soil is being continually removed so that the dark-colored surface soil at any time consists essentially and fundamentally only of the lower part of the dark-colored layer that should be present, the upper part having been removed by erosion. The layer of dark-colored material is thin and the dark color is less intense than in a region where the soils have not been subjected to severe erosion. In other respects the Colby soils are very similar to the Moody soils.

A small area of Moody soils lies on the south side of Platte River in Nebraska, the main area being north of it. South and to a slight extent west of this area in southern Nebraska and extending also southward into the northern part of Kansas, is an area of soils identified in detailed work as members of the Hastings, Crete, Butler, Fillmore, and Scott series. The last three series occupy only small areas, lying in situations where the erosion of the existing topographic cycle has not yet reached and in which, therefore, the soils are subject to imperfect drainage. Even in the aggregate, however, the areas of these soils are very small so that practically all the total area is dominated by Hastings and Crete soils, but on the soil map only the Crete and Scott soils are shown. (Pl. 5, secs. 6 and 7.)

Hastings soils are very similar to Moody soils. Like the Moody they have been derived from a layer of silt which in this case seems to have been derived from the west or northwest. Practically the only difference between the Hastings and Moody soils is an accumulation, in the lower part of the subsoil of the former, of a zone of slight clay concentration. These soils were differentiated from the Holdrege soils, which occupy the region immediately west of them, entirely on the basis of the presence of a very slight concentration of clay in the subsoil of the Hastings. Since the Hastings soils, however, are neutral and the colloids are well flocculated, giving a well-defined granular structure to the dark-colored layer, it is apparent that the clay concentration has not taken place because of the acidity of the surface soil. It is not an illuviated horizon like the B horizon of Podzolic soils. It is apparent that the easiest and most simple explanation of its concentration is that it is the product of the presence in the parent material of an extremely small percentage of sodium salts.

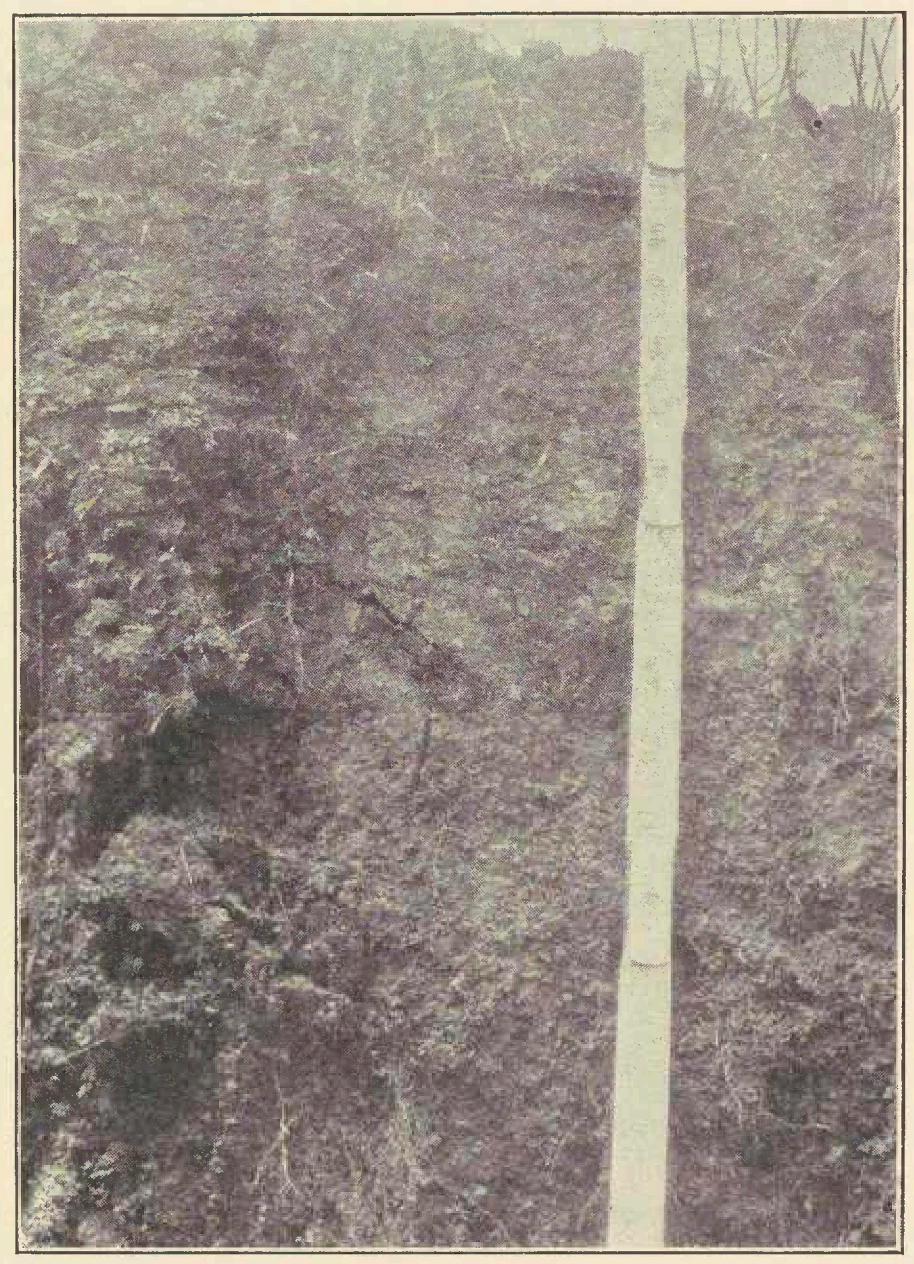


FIGURE 37.—Profile of Crete silt loam, in Seward County, Nebr., showing lamination in layer 1 and granulation in layer 2.

The Hastings soils (fig. 36) have been differentiated in detailed mapping from the Crete soils (fig. 37) on the basis of the accumulation in the subsoil of the latter, below the dark-colored layer, of a well-defined concentration of clay forming a claypan. In the Butler, Fillmore, and Scott soils the claypan is still better defined, reaching its maximum development in the Fillmore. No other explanation of the presence of this concentration of clay than that suggested for the very slight concentration in the Hastings soils has yet been worked out. As the Holdrege soils have no zone of clay concentration and the Hastings soils which lie immediately east of them have a very slight concentration only, the concentration increasing in intensity eastward, it would seem to indicate that it has a relationship to the increasing rainfall. Since it occurs, however, only on the flattest areas, it is possible that it may have a relation to the presence of ground water and the length of the wet period each year during which ground water lies at a slight depth in the soil. Since this period of time increases, presumably, with the amount of rainfall and therefore eastward, it is apparent that the concentration of a claypan has a relationship to ground water. The occurrence of ground water is not uniformly associated, throughout the United States, with the presence of a claypan and it is apparent that some other factor has accompanied that of the ground water in causing its development.

The dark-colored surface layer of the Crete and Hastings soils is heavier in texture and fully as dark in color as the corresponding horizon of the Moody soils. It has a somewhat better developed granular structure than the latter. It is somewhat thicker than the surface soil of the Moody soils, and the zone of lime carbonate accumulation is somewhat better developed, usually occurring in the lower part, immediately beneath the claypan.

Associated with the Hastings and Crete soils throughout the region of their occurrence are soils developing on gently rolling areas in which no claypan is present. Since the parent material is essentially identical, this relationship still further suggests the influence of ground water in the formation of the claypan.

West of the area in which the Hastings and Crete soils occur is an area of Holdredge soils. These soils occupy a large area in Nebraska south of the Platte River and west of the Hastings area and also extend southward into north-central Kansas. These soils have also developed from a layer of silt identical or very similar in character to that from which the Hastings, Crete, and Moody soils have been derived. They occur in areas of smooth relief and have developed the normal Chernozem profile so far as that concerns the presence of the zone of carbonate accumulation. The color is not so dark as that of the true Chernozems in the Dakotas, and the zone of carbonate accumulation is not so highly developed. It is as highly developed, however, as in the soils derived from the layer of silty material, taken as a whole. Throughout the areas of Pedocals in the United States the zone of carbonate accumulation, all other things

being equal, is less well developed in soils derived from loess than in those derived from heavier parent material.

The dark-colored horizon of the Holdrege soils extends to a depth of about 15 inches, and it is underlain by a brown silty horizon essentially identical in texture with the surface soil but in which calcium carbonate has not accumulated. The carbonate lies at a depth of about 2½ or 3 feet beneath the surface. The parent material beneath is calcareous and silty. Although the Holdrege soils have developed on very smooth surfaces, they seem in no case to have been influenced in their development by the presence of ground water. This is probably owing to the low rainfall, these soils lying on the extreme western edge of what we regard in this country as the Chernozem belt.

In central Kansas, occupying a large area lying mainly north of the Arkansas River, lies an area in which the soils are identified as members of the Hays series. This series of soils has not yet been defined in the regular work of the Soil Survey and is being created in this publication for the first time. Practically no detailed field studies of soils have been made in central Kansas. The Hays soils, as shown on the

FIGURE 38.—Skip-row method of growing grain sorghum, Fisher County, Tex.

map, therefore, are the result of incidental examination of soils by members of the Soil Survey staff in crossing this region in the progress of their regular work. It is well known that the soils of the area are not uniform. Enough work has been done, however, to show that these soils are members of the Chernozem group, and chemical examination of a few samples collected in the region show that their characteristics are moderately well developed. They are relatively heavy as compared with the soils farther north, as they have been derived from material accumulated by the disintegration of shales rather than from wind-blown silts.

The surface soils are dark colored but not black. They do not differ in this respect from the Holdrege, and their heavier texture offsets their more southern situation. The dark-colored layer is thicker than in the Holdrege soils, and the zone of calcium carbonate accumulation lies immediately below it.

To a greater extent than in the silty soils, the organic matter in the Hays soils has been carried downward into the upper part of the zone of carbonate accumulation. This has been made possible by the cracking of the soil due to shrinking which takes place when the soil dries in late summer. When rains start in the winter or spring,

FIGURE 39.—Cotton on Red soils (Amarillo), near Roby, Fisher County, Tex.

dark-colored surface material is carried down along these cracks before the easy downward passage of moisture has been stopped by swelling of the material.

In the southeastern part of the area mapped as Hays, lying mainly south of the Arkansas River, east of Great Bend, Kans., is an area in which the parent material has a reddish color. This soil has been differentiated as a separate soil on some old maps covering small areas in this region, but since the soil profile above the parent material in all its essential characteristics, so far as is now known, is identical with that of the Hays soils, these soils have been included with the Hays. This is fully justified, since it is well known, as already stated, that the Hays soils are not uniform throughout the area of their occurrence.

It is not yet known to what extent claypan development has taken place in the eastern part of the Hays area. It is known that the Crete and Hastings soils, or soils with identical profiles, extend southward from their main area of occurrence in Nebraska into east-central Kansas. An area of Crete soils has been mapped northeast of the main Hays area, and it is probable that the same kind of development has been going on still farther southward but this can not be determined until further studies have been made.

From the southern boundary of Kansas, the western boundary of the Chernozem belt bends westward because of the rather rapidly increasing elevation southward from Arkansas River. The eastern boundary continues southward, however, so that in northwestern Texas the belt is broader than in Kansas. It extends westward in the panhandle region of Texas more than halfway from the Oklahoma boundary to the New Mexico boundary. The northern panhandle region, because of its elevation, has an effective moisture supply very similar to that of central Kansas in the central part of the Hays soils area. The soils around Amarillo, Tex., for example, lie on smooth areas and are practically as dark colored as are the soils in the southern part of the Hays area in Kansas. In all this region, however, south of Kansas, the soils have a well-defined reddish shade. When the mineral material has been separated from the organic matter with which it is mixed in the surface soil, the latter has a reddish-brown color and the material below the dark-colored surface horizon is reddish. It becomes more strongly reddish southward so that in the region of Lubbock, Tex., and southward, where well drained and where the color is not obscured by the presence of organic matter, the soil is definitely reddish. The normal well-developed dark-colored soils lying on smooth relief throughout this region are identified as members of the Amarillo and Abilene series. The Amarillo soils, however, cover a much larger total area than the Abilene. The dominant soil as shown on the map covering this region is mapped as Amarillo. Figure 38 shows a field of grain sorghum grown on these soils in Fisher County, Tex.

The soils of the Amarillo series extend from the northern part of northwest Texas (figs. 39 and 40) southward to the Edwards Plateau a little south of the latitude of the southeast corner of New Mexico. This range of latitude is 5°, and the distance is about 350 miles. This is a wide range and, when considered in connection with a decrease in elevation southward, it is evident that some change in soil character must have taken place.[23]

The Amarillo soils in the northern panhandle of Texas, in the vicinity of Amarillo and northward, have a well-defined dark reddish-brown color. Southward the surface soil becomes less dark brown, and in the southern part of the panhandle region it is less dark and more red.

The profile of the Amarillo soils is characterized by a very dark brown surface horizon extending to a depth ranging from 15 to 18 inches. It has a well-defined

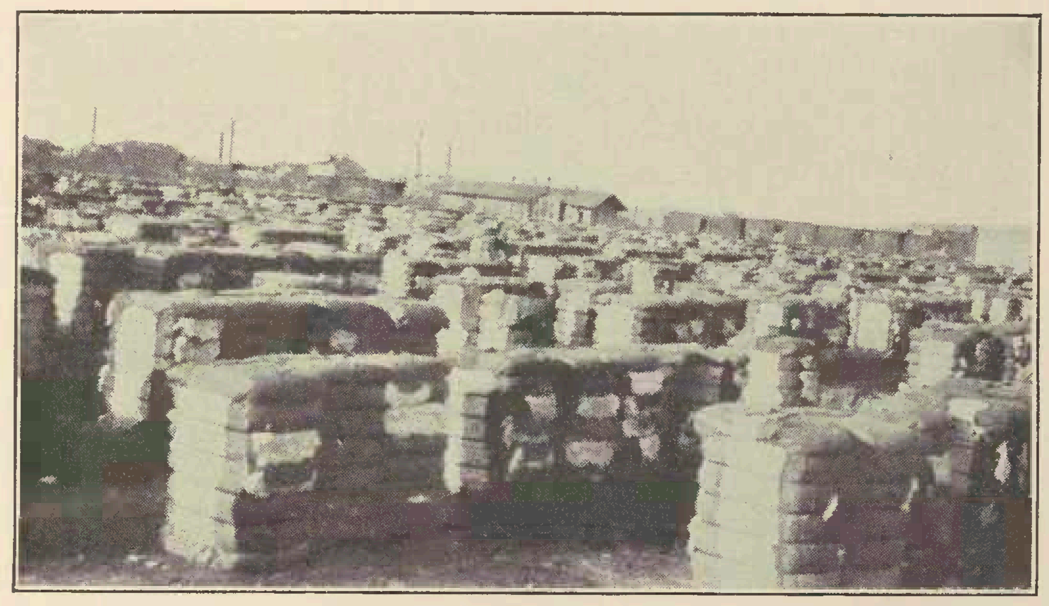


FIGURE 40.—A cotton yard at a cotton gin, Spur, Tex.

granular structure, is uneluviated, and in most places is comparatively heavy in texture. It is underlain by light-brown or faintly reddish brown material a few inches thick, and this, in turn, is underlain by the usual zone of carbonate accumulation which in most places is pinkish or reddish. The parent material consists of Tertiary deposits which are usually unconsolidated but calcareous.

A considerable area of Amarillo soils is shown on the map in western Oklahoma. Since practically no detailed mapping has been done in Oklahoma, it is not definitely known that these soils are members of the Amarillo series. They lie on the eroded plains east of the foot of the high plains escarpment and have been developed from other materials than the materials of the high plains on which typical Amarillo soils have developed. They belong in the same great soil belt as the Amarillo soils, or in other words they are members of the Chernozem group of soils, but whether they are similar to the Amarillo soils, to the Abilene soils, or to an entirely new soil series, not heretofore differentiated in soil mapping, is not now known.

Amarillo sand, occupying a considerable area along the breaks of the plains east of the large continuous area of Amarillo soils, could have been designated merely as Sand in the same way that Sand in most other parts of the United States is shown. Since, however, these sands have not been so thoroughly leached as those in the sand-hill belt of the Carolinas, it was thought best to differentiate them from the leached sands.

In Texas, in physiographic situations comparable to those in which the Amarillo soils are mapped in Oklahoma, the mature soils have been identified as members of the Abilene series. The Abilene soils have a dark-brown surface horizon about a foot thick. The percentage of organic matter is relatively high but not sufficient to give the material a black color. The mineral material with which the organic matter is mixed is pinkish or reddish, so that the color of the soil in the field when dry is dark reddish brown. The surface horizon is underlain by a layer of red material containing very little organic matter, though the transition from the surface soil is gradual. This layer is usually less than a foot thick and is underlain by the zone of carbonate accumulation. The material in the latter zone is pinkish or red, not so red, however, as that of the horizon above, because of the presence of a high percentage of calcium carbonate which is well distributed throughout the soil mass. The thickness of the layer ranges up to 2 feet or more but is rarely indurated to caliche, a limestonelike layer. As shown on the large soil map, the Abilene soils include the Foard soils. The difference between the two, however, is largely one of parent material, and since in this region, where the material has not been leached by high rainfall, the influence of the parent material is confined largely to the texture of the soils, and since both the Abilene and Foard soils are comparatively heavy, consisting of loams, it is apparent

[23] The Amarillo series was defined originally on the basis of the characteristics of the reddish Pedocals occurring on slopes and other rather excessively drained areas in the vicinity of Amarillo, Tex. Such soils occupy, however, small areas in the vicinity of Amarillo, but in reconnaissance mapping in the region all the mature soils were included in this series. As mapping was extended southward on the high plains of Texas not merely the excessively drained areas but all the soils, even those on flat areas, were found to be red. When detailed mapping was taken up in the Amarillo region in recent years, the fact that the dominant soils, those on the smooth areas of the district, are not red had to be recognized. These dark-colored soils without reddish mineral material or without decidedly reddish subsoils were given independent status as the Pullman series. On the soil map (pl. 5, secs. 6 and 11) in this publication, however, the soils of the region originally defined as Amarillo have been shown as such, but it should be remembered that in the northern part of the areas shown, these soils are dominantly not red.

that the influence of the parent material in producing those features on the basis of which they are differentiated has been relatively insignificant.

The Abilene soils lie within the undulating or rolling plains east of the high plains escarpment but on smooth or flat areas within these plains. In the areas where the relief is strongly rolling or hilly, where the soil profile has not attained more than incipient development, and where, therefore, the character of the parent material, in this case consisting of the red shales and sandstones of Permian age, expresses itself definitely, especially in the color of the soil, the soils have been mapped as members of the Vernon series. The Vernon soils are in progress of development into soils equivalent to the Abilene, but in very rare cases have they attained anything like maturity of development. The Vernon soils are red, but the redness is that of the parent rock and not that of oxidation by the weathering processes which are developing these soils. They contain no zone of carbonate accumulation and have not accumulated sufficient organic matter in the surface horizon to give them a dark color. This is owing in part to the erosion to which these soils are subjected and have been subjected for a long time and in part to the less luxuriant growth of grass on these soils than on the mature soils like the Amarillo and the Abilene. The vegetation on the Vernon soils is partly grass and partly brush, consisting mainly of mesquite brush though the cover is very open.

The Vernon soils extend northward into western Oklahoma also. Since they are undeveloped soils, consisting mainly of parent material, and since the Permian "Red Beds" underlie western Oklahoma, it is apparent that the soils mapped Vernon in the western part of that State are true Vernon.

The Abilene soils extend southward to the northern boundary of the Edwards Plateau, which is a large area underlain by limestone beds, lying in a horizontal position, and extending from the southern terminus of the high plains lying a short distance south of the line of the Texas & Pacific Railway southward to a line running westward from San Antonio, Tex., along the line of the Southern Pacific Railroad. The eastern boundary is approximately that of the Chernozem belt, and the western boundary lies east of Pecos River, except in the extreme southern part of the State, where it extends west of that river. All but the western part of this area lies in the Chernozem belt. That part lying within the Chernozem belt is covered by a mixed growth of grass and scrub oak. The growth of brush and trees is considerably more dense than that on the Vernon soils east of the high plains, but it is not sufficiently dense to prevent the growth of a good cover of grass. The soils are almost invariably shallow, but in the few localities where limestones have decomposed to a depth sufficient to allow the development of a normal profile the profile is that of a soil of the southern Chernozems. The color of the surface soil in these localities, as well as elsewhere on the Edwards Plateau, is darker than is that of the Abilene soils in the same region. This is apparently due to the high percentage of calcium carbonate present in these soils. They partake, to a considerable extent in this respect, of the character of Rendzinas [24] rather than of the normal soils of the region or of true Chernozems.

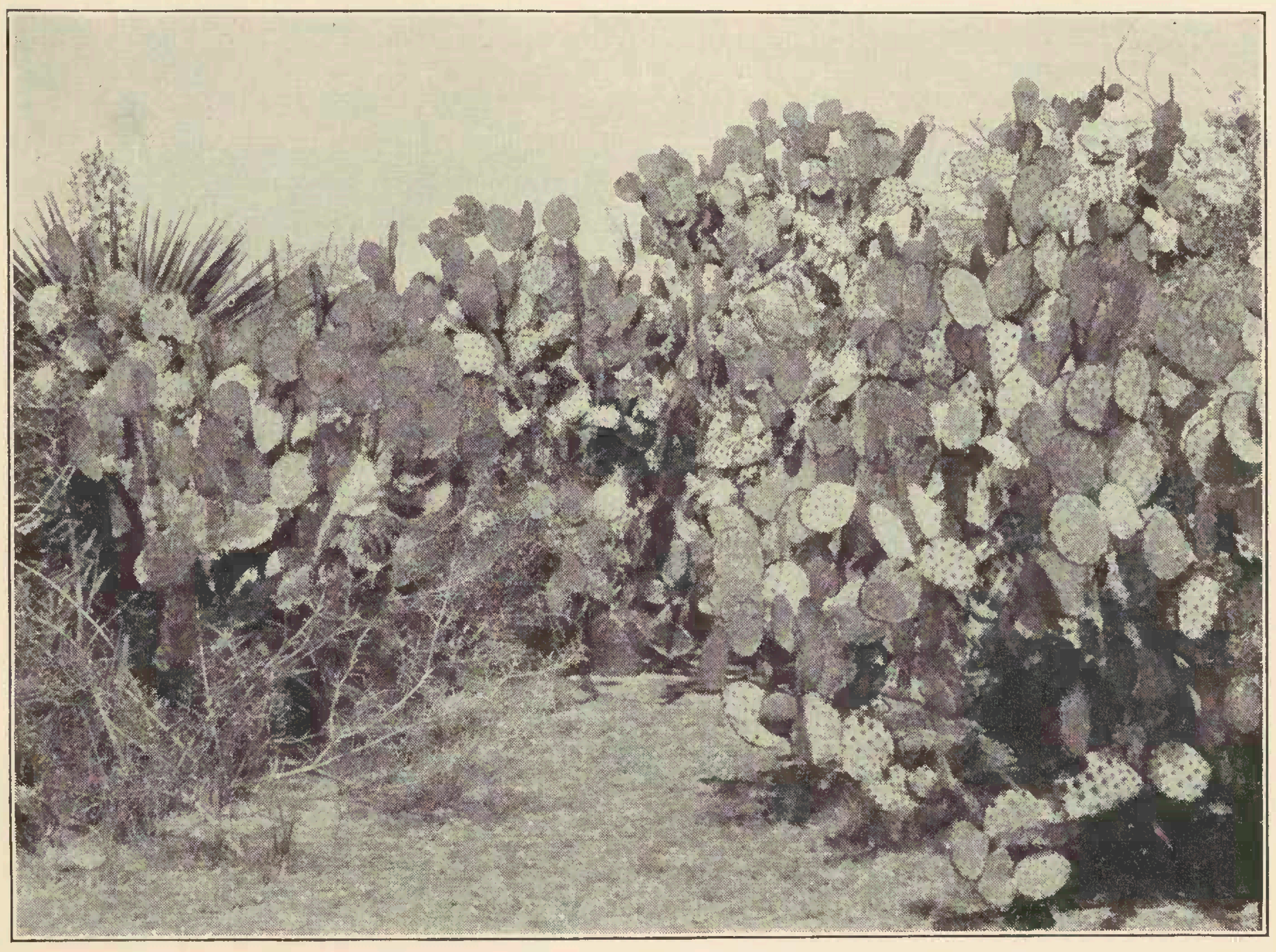


FIGURE 41.—Cacti on southern Chernozems, Cameron County, Tex.

FIGURE 42.—A field of onions near Laredo, Webb County, Tex.

In the few places where the normal profile has developed these soils are not Rendzinas, although they may still inherit some Rendzina characteristics, but in other places, and this includes 95 per cent of the whole area, it is apparent that the Rendzina characteristics predominate. Notwithstanding this fact, the surface soil, which in few places is more than 12 inches thick, is underlain by a thin coating, rarely more than 2 or 3 inches thick, overlying the limestone, of accumulated calcium carbonate in the form of an indurated layer, or caliche. The caliche layer is usually thin, but in the comparatively smooth areas where soil development has proceeded somewhat it is generally present. In such cases these shallow soils consist mainly of a dark-colored horizon and the caliche, though there may be a thin layer of reddish clay lying immediately beneath the dark-colored horizon and above the caliche. These soils are mapped as members of the Valera series and consist mainly of stony clay loams.

The southern boundary of the Edwards Plateau is marked by a southward-facing escarpment. Immediately south of it is an east-west belt, several miles wide, consisting mainly of members of the Victoria series. Figure 41 shows the natural vegetation on these soils, and figure 42 shows a field of onions grown on them.

These are soils developed mainly from material spread out in a plain by streams flowing out of the Edwards Plateau and therefore contain a considerable amount of calcium-carbonate material. Soils of this belt are covered by brush, the growth of which in many places is very dense. Unlike the Edwards Plateau, the proportion of grass in the vegetative cover is small. The color of these soils is dark, but not so black as that of soils on the Edwards Plateau. In general they are young soils. On low ridges and in other places, where because of slope the soils are dry and oxidation is active, they develop a red color which extends to the surface. Elsewhere the dark-colored material in the surface soil obscures the red. Where development has proceeded far enough these soils are characterized by a zone of carbonate accumulation which in some places has been developed into a caliche. They do not differ very greatly, either in character of parent material or in stage of development, from the Abilene soils, but they are somewhat more red because of their more southerly position. They have developed under a more dense vegetative cover than have the Abilene soils, on the Victoria soils the cover being brush, whereas the Abilene soils have developed under grass, although they have an open cover of mesquite. They are shown on the soil map (pl. 5, sec. 11) as Victoria soils.

The soils of the region south of the belt of Victoria soils lying immediately south of the Edwards Plateau, extending to the Rio Grande, are largely unknown. It is known, however, that the region is belted. The soils, so far as their detailed characteristics are concerned, run in a series of southwest-northeast belts. The soils of most of the area, except the western part, belong in the Chernozem belt, but they are differentiated into series on the basis of certain characteristics, one of which includes the character of the parent material. In the lowland belts of this region the soils have been developed, in most cases, from marls or soft limestone. In the higher belts, none of which is more than 100 or 200 feet above the lowlands, the soils have developed from highly calcareous beds which contain some indurated limestones. In the lowland belts the soils are dark, most of them almost black. The blackness is apparently an expression of their development from marls and of their imperfect state of development. They still show Rendzina characteristics. These soils occupy the southwestward extension of belts which, east of the Chernozem belt, are mapped as members of the Houston series. It will be remembered that the Houston soils are typical Rendzinas. The same soils south and west of the Chernozem belt boundary are Rendzinalike but are identified and shown on the map as members of the Victoria rather than the Houston series, because they lie within the Chernozem belt. In essential fundamental characteristics, however, they do not differ very greatly from the Houston soils. Their differentiation is chiefly on a pedological rather than a practical basis.

There are three of these belts of dark-colored soils developed from marls or marly materials. One lies along the Gulf and is a southwestward extension of the belt of recently uplifted coastal deposits on which the Lake Charles soils have developed in southern Texas east of the boundary of the Chernozem belt. The second belt, lying north of this one, is continuous with the belt of Houston soils running parallel to the coast through Gonzales, Fayette, and Lavaca Counties, and the third is the extension of the main Houston belt running southwestward from Dallas and Fort Worth to San Antonio.

Between these areas of dark-colored soils lie, on the low ridges of the region, soils which have a brown or reddish-brown color, darkened by organic matter and underlain by red clay derived from limestone. Where the soils have lain in place for a long time a thick caliche has been accumulated, amounting in some places to 6 feet or more of practically solid limestone, and beneath this stringers of limestone extend downward into the calcareous clay for another 6 feet or deeper. This is especially true of these dark-colored soils in northern Hidalgo and Willacy Counties, where the surface is covered by an accumulation of sand. These soils are shown on the large map as members of the Duval series, but in detailed mapping those covered with a layer of sand are mapped as members of the Nueces series. A number of other series have been differentiated in the few areas that have been studied in detail.

It should be borne in mind that the differentiation of soils in this region is based on a very limited amount of information, since very little detailed work has been done. No field studies have been made along the Rio Grande west of the western boundary of Hidalgo County. In this region the soils are shown on the map as members of the Duval series, but it is not known exactly what their characteristics are, nor is it known whether the soils within this region are relatively uniform in character. West of the belt of Victoria soils, which is the extreme southward or Chernozem extension of the coastal belt of Lake Charles soils, a belt of soils, developed to a large extent, if not entirely, from old alluvial deposits of that stream, lies along the Rio Grande in southern Texas. These soils are relatively young, but have developed a subnormal profile. They are marked by a faint accumulation of calcium carbonate in the subsoil, and the surface soil is rich brown or dark brown. These are the soils on which the irrigated agriculture of the region is developed. They are mapped mainly as members of the Hidalgo series in detailed mapping, but have been combined with the Duval soils on the soil map. The Duval soils seem to contain features resulting from a more advanced stage of soil development under the regional environment than the Hidalgo

[24] Soils still young, developing from soft limestones and marls from which the carbonate has not yet been removed from the surface layer. The bases saturate the organic and other colloids, which retain the organic matter, and the latter gives the soils a dark color. (See Houston black clay, p. 42.)

soils. They have developed a reddish subsoil, but have a dark-brown surface soil except where eroded. (Pl. 5, sec. 11.)

It has already been stated that the Pedocals of the Great Plains region are divided into a number of groups distributed in north-south belts, the most easterly belt being that of the Chernozems, which has just been described. The soils of the belts which succeed each other westward differ mainly in the color of the surface layer which contains the organic matter. They differ somewhat in other respects, but this is the most striking difference and is the one on which the soils here designated as Pedocals were divided into subgroups.

No area extending entirely across the width of the Great Plains has been mapped according to the modern point of view. Mapping of an area extending from northeastern Montana entirely across that part of the State lying within the Great Plains, from the Canadian line southward to Missouri River, has just been completed. Work on the eastern extension of this belt across North Dakota, needed to complete a belt entirely across the Great Plains, has not been completed. In practically all cases, with the exception of this comparatively narrow belt in northern Montana, the mapping of the soils of the Great Plains as shown on the large soil map in this publication is based to a slight extent on general reconnaissance surveys, but mainly on general knowledge of the character of the soils obtained by crossing the region in traveling from one part of the country to another. In these general studies no actual field mapping has been done. The deficiencies of such work for the purpose of general mapping, such as that in this publication, are not so great, however, as it may at first seem.

The Great Plains have a smooth land surface, are covered uniformly, or almost so, with grass, the rainfall decreases gradually from east to west, and the changes in temperature from south to north take place so gradually that practically no effect is noticeable within small areas. The smooth relief and the regular distribution of the dynamic factors of soil development have resulted in the production of soils which are uniform over large areas. The general characteristics of soils developed under such conditions have wide distribution and are not modified by local conditions to such an extent as the soils of the eastern part of the United States. The soil map in this publication attempts to show soils defined on broad features only.

FIGURE 43.—Profile of a Dark-Brown soil, near Calgary, Canada.

THE DARK-BROWN AND BROWN SOILS

The soils of a belt lying immediately west of the Chernozem belt constitute the Dark-Brown soils. The corresponding soils in Russia are called Chestnut-Brown soils. The chestnut-brown color contains an element of red. Since in Russia the soil belts run east-west and the Chestnut-Brown belt lies south of the Chernozem belt, and in a region therefore of higher temperature, the soils of the whole belt are comparatively uniform in color, and because of their southern latitude they have been more highly oxidized than those farther north and have a shade of red in their color. In the United States the chestnut-brown color is present only in a relatively small area in the central or Kansas part of the belt of Dark-Brown soils. North of Kansas the surface soil is dark brown and south of that State is dark reddish brown, the soils becoming less dark in color southward. The true Chestnut-Brown soils, like the true Chernozems, occupy only a small part of the north-south belt in which the soil color is slightly less dark than that of the Chernozems. For this reason the soils of the belt are called Dark-Brown rather than Chestnut-Brown soils.

The belt of Dark-Brown soils includes the eastern part of the Great Plains west of the western boundary of the Chernozem belt. On account of the gradual decrease westward of the dark color of the soil, considerable areas of the Great Plains are occupied by soils of the Pedocal group too light in color to be included in the Dark-Brown soils. Theoretically, these soils should occupy a continuous belt stretching, like the Dark-Brown soils, from north to south entirely across the country, and it is easily possible to establish such a belt. On the soil map in this publication, however, the belt of Dark-Brown soils extends westward to the mountains, except a few large areas, notwithstanding the well-known fact that the color of the soils in the western part of the belt is lighter than that in the eastern part.

In a narrow belt lying along the mountain front, except in those places where the mountains are low, and extending eastward a few miles, usually less than 10, the soils are darker than farther eastward, in some cases, especially in Montana, being black. This belt is too narrow to be shown on the soil map and is included, therefore, in the belt of Dark-Brown soils.

In a large area of the Great Plains of Montana, with the town of Shelby occupying approximately the center, the soils are brown. This is an area in which the rainfall is low, amounting to only about 14 inches, and the grass cover has not been sufficiently dense to give the soil a dark-brown color. The zone of carbonate accumulation lies at less depth, usually very little more than a foot, than in the Dark-Brown belt.

Another large area of Brown soils lies along South Platte River in Colorado, a third along Arkansas River in southern Colorado, and a fourth in New Mexico and in the Trans-Pecos country of Texas.

Within the Rocky Mountain belt, most of which is shown on the map as rough land, there are many areas typical of all the great soil groups found in the Great Plains and eastward to the Atlantic. Many of these are shown on the soil map with approximate accuracy as to general location. The Dark-Brown and Brown soils of the Great Plains and of those areas within the mountains are described below and without seperate headings. The general character only of these soils is known, even on the Great Plains, and of those within the mountains still less is known.

It was stated on a preceding page that although the belts containing these groups of soils extend across the United States in a north-south direction, near the northern boundary of the United States their direction changes to a northwesterly course. The eastern boundary of the Chernozem belt does not turn south of the international. boundary but begins a short distance north of Winnipeg, Canada. The western boundary, however (pl. 2), turns northwestward from the southern boundary of North Dakota and includes a small area in the northeastern corner of Montana. The western boundary of the Dark-Brown belt trends sharply northwestward from northeastern Wyoming and crosses the Canadian boundary at the eastern foot of the Rocky Mountains. (Fig. 43.) In Montana the distribution of the Dark-Brown soils has been modified by the occurrence of a number of isolated mountain groups, whose influence will be discussed when that part of the belt has been taken up.

Since the Chernozem, Dark-Brown, and Brown soils lie in the Great Plains east of the Rocky Mountains, and the Gray Desert soils, the fourth group, in the Great Basin desert region, and since the Brown soils, on the basis of the information obtained to the present time, occur in a discontinuous belt, it will be convenient to describe the soils of both the Dark-Brown and Brown belts together. The slight difference between the soils of the two groups and their relatively slight importance agriculturally add to the justification of this procedure.

In the description of the Chernozem soils in North Dakota, the Williams soils, lying intermediate in color between the Chernozems and the Dark-Brown soils, were included with the Chernozems.

Because of the almost complete lack of results of detailed field studies of soils in the Great Plains west of the Chernozem belt, the number of soil series shown within

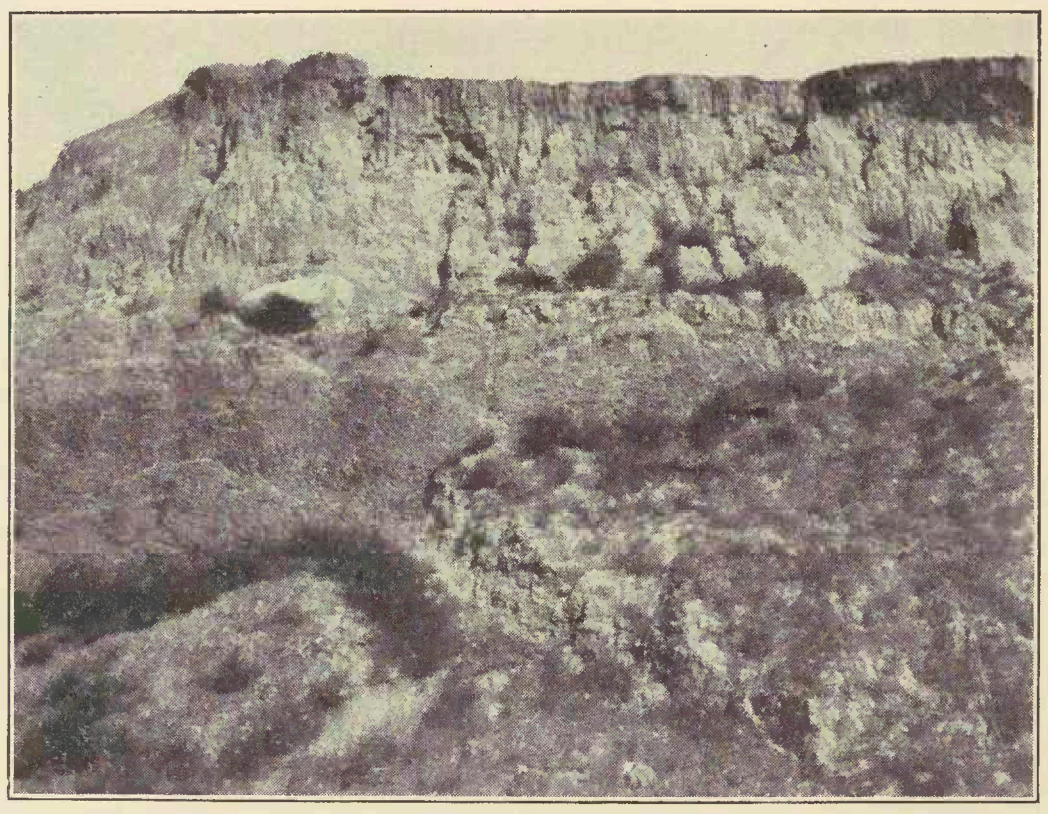


FIGURE 44.—Profile of a Dark-Brown soil, near Bismarck, N. Dak.

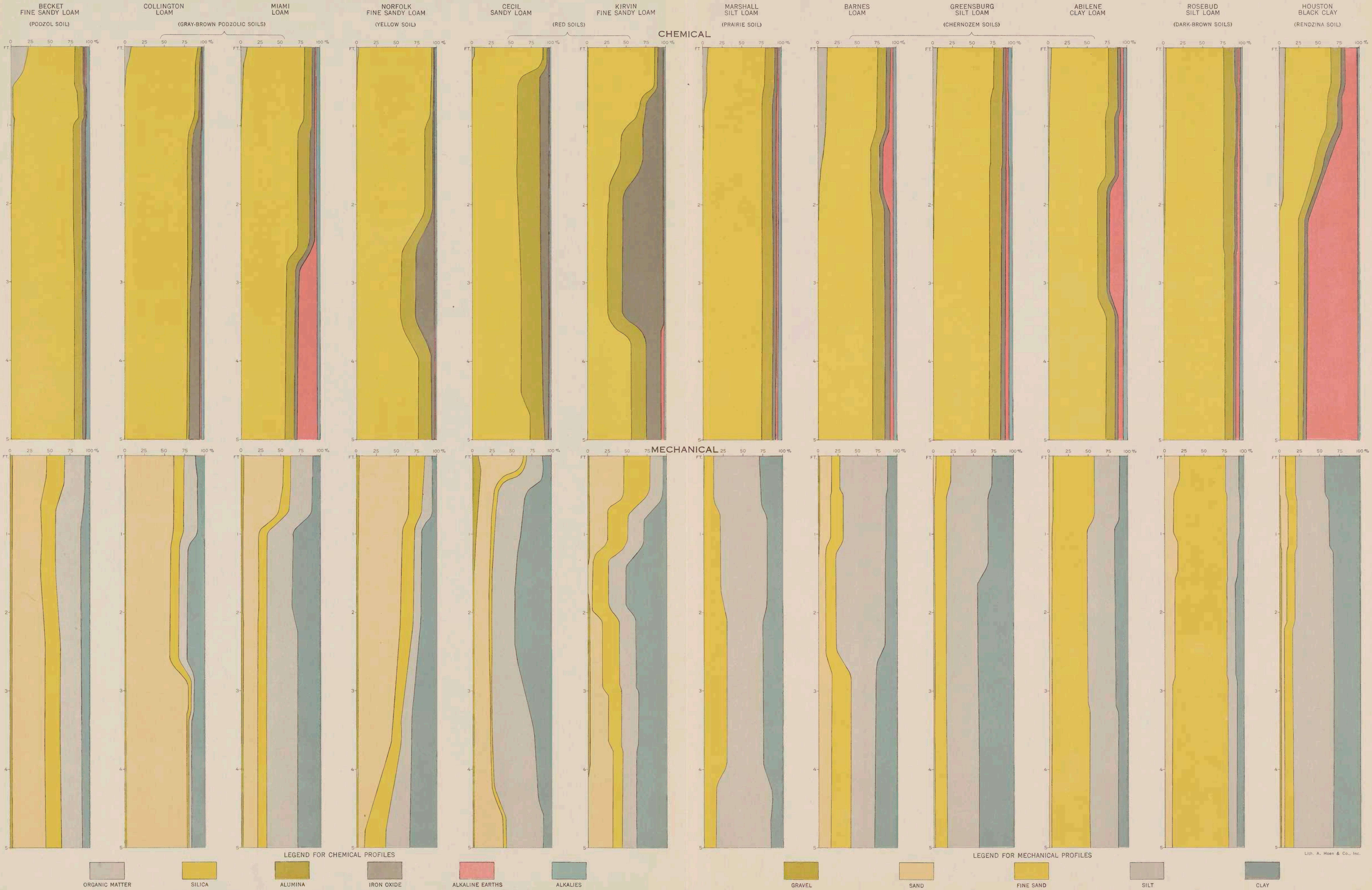
the Dark-Brown and Brown soils belts on the soil map is small, and in most cases their distribution has been determined by widely scattered and occasional studies only[2] A strip across that part of Montana lying in the Great Plains north of Missouri River is the largest area that has been carefully studied and mapped. A number of projects covering small areas have been studied in western Nebraska, one in eastern Wyoming, two in Colorado, and several in Texas.

In northeastern Montana the Williams soils cover an area of a few counties. West of the Williams area a series of soils identified as members of the Daniels series belongs in the same great group as the Williams. They are very dark brown where well developed, with a well-defined carbonate zone at a depth of about 2 feet. They have been differentiated from the Williams soils because of having developed from a thick bed of gravel, and they occur on uneroded remnants of a gravel plateau originally covering a much larger area.

The soils occupying a large area west of the Daniels area, extending westward to a north-and-south line about 20 miles west of Havre and southward from beyond the Canadian boundary nearly to Missouri River, are shown on the map as members of the Scobey series. These are well-defined Dark-Brown soils, with a zone of lime accumulation lying at a depth ranging from 12 to 20 inches. The surface horizon, which is about 2 inches thick, is loose, deflocculated, and usually sandy. Beneath this lies a firm, usually roughly prismatic dark-brown horizon with rather well defined granulation in the upper inch or two. The lower part of the horizon, ranging from 6 to 12 inches in thickness, is light brown or brown. The lime concentration zone lies beneath. The parent material is calcareous glacial drift. Throughout the area of their occurrence the Scobey soils have an imperfectly developed columnar or prismatic dark-colored horizon. This characteristic is a noticeable feature of the Dark-Brown soils, the prismatic breakage being better defined in the lower than in the upper part of the horizon.

A belt of Phillips soils, lying within the area of Scobey soils, is about 20 miles wide on the Canadian boundary in the northeast corner of Hill County and the northwest corner of Blaine County and extends southeastward to Missouri River, in Phillips County. It consists of that part of the belt of Scobey soils which contains a very large number of "slick spots" or Solonetz areas. All the features of the Solonetz profile are found in this belt, ranging from the typical Scobey profile, in which the columnar breakage in the dark-colored horizon may be interpreted as a faint development of Solonetz features, to areas of well-developed microrelief, in which the surface is bare of vegetation and heavy columnar clay lies beneath a gray highly porous structureless layer an inch thick. Beneath the heavy tough columnar claypan, at

APPROXIMATE CHEMICAL AND MECHANICAL COMPOSITION PROFILES OF REPRESENTATIVE SOILS



EXPLANATION OF MECHANICAL AND CHEMICAL COMPOSITION CHARTS

The charts show the approximate chemical and mechanical composition of samples from representative soils, collected carefully according to soil horizons, of six of the great soil groups of the United States and one Rendzina profile. An analysis of material from each horizon was made. This composition was assumed, in constructing the chart, to represent the material half way between the bottom and top of the horizon. Points were laid off across the chart half way between the top and bottom of each horizon, the distances between adjacent ones being proportional to the magnitude of the percentage composition of the constituent represented. These points were connected by lines, but in drawing them their course between points was determined by knowledge of the detailed characteristics of the soil profiles obtained by field study.

The charts were constructed from the loss-on-ignition free composition of the soils, giving no recognition of the presence of organic matter. After construction the percentage of organic matter obtained by multiplying the percentage of nitrogen by 23 was placed on the chart. By this means some of the silica is obliterated by the color for organic matter. In reading the chart therefore the organic matter and mineral matter should be read entirely independently. The relative percentage of silica in the surface soil can be determined only by measuring from the left boundary of the chart to the silica-alumina boundary and not from the apparent silica-organic matter boundary to the silica-alumina boundary. The mechanical composition charts were constructed directly from the mechanical analyses tables submitted from the laboratory without recalculation.

a depth of about 12 inches, lies the zone of calcium-carbonate accumulation containing also abundant gypsum crystals.

Solonetz soils in many stages of development and degradation occupy a great number of spots and small areas, mainly in the western part of the United States. As they do not occupy any large continuous areas, they have not been given recognition as one of the great soil groups. They have been included within and undifferentiated from the soils with which they are associated, except the area of Phillips soils, just as the Rendzinas of Texas have been included in the Prairie soils and those of Alabama and Mississippi in the Red and Yellow soils. They are characterized by the presence of a heavy tough clay horizon usually at a depth of less than 2 feet. This is usually accounted for as a result arising from the presence of a very small content of sodium carbonate in the soil material. These soils were first studied by Russian soil scientists, and the name here used is a Russian word.

Over large areas within the Great Plains these spots consist of slight depressions about 6 inches deep, caused by the removal of the material overlying the heavy tough clay horizon. The depressions are usually round or oblong and range up to 50 feet in diameter. A great number of these depressions in an area produces what has long been designated by the Russian soil scientists as microrelief.

Between the dark-colored Scobey soils (fig. 45) occupying the large area extending from Havre to Scobey and a smaller area lying west of Cut Bank is a large area covered by Joplin soils. These are Brown soils developed under an annual rainfall ranging from 8 to 12 inches and a grass cover less dense than that under which the Scobey soils have developed, where the rainfall ranges from 12 to 16 inches. The Joplin soils differ from the Scobey in the brown rather than dark-brown color of the second horizon. The parent material is essentially the same in both cases.

The central part of the area of Joplin soils is the point of lowest rainfall and least vigorous growth of grass cover in northern Montana. The rainfall decreases from the eastern part of the State westward to this point, beyond which it increases, owing presumably to the influence of the mountains. From the longitude of Cut Bank west-

FIGURE 45.—Profile of a Dark-Brown (Scobey) soil, near Glasgow, Mont.

ward the soils are dark, the darkness increasing westward to the mountains, where a forest cover and higher rainfall cause development of Podzolic soils. Except for a narrow belt immediately east of the mountains, where the soils are dark and have developed from thick gravel deposits spread out from points where the rivers flow from the mountains into the plains, these soils, developed in part from glacial drift and in part from gravels, are shown on the map as Scobey. Along the mountain front where developed entirely from the gravel beds and where the color is dark they are identified, for mapping purposes, as Daniels soils. Where developed from glacial drift they are identified as Williams soils. In detailed mapping this mountain fringe belt contains a large number of soils.

Along both sides of Missouri River above the mouth of Milk River, mainly above the mouth of Musselshell River, is a belt of soils identified in reconnaissance mapping as members of the Lismas series. They are undeveloped soils consisting mainly of disintegrated shale material. The imperfect profile development is partly due to their occurrence on uneven relief, but mainly to the heavy texture of the material. The Pierre soils are also young and have developed from shales of essentially the same character as those in the Lismas region. In general character soils of the two series are alike and are combined on the map as the Pierre soils. The Pierre soils occupy large areas in western South Dakota and adjacent parts of Montana and Wyoming.

Belts of badlands lie along all the streams in southeastern Montana and in the Dakotas. The soils in such areas are essentially like the Pierre soils. The relief is rougher than that in areas of Pierre soils taken as a whole, so that the areas of soils with even a slight development of profile is proportionally smaller. The areas of Pierre soils and the badlands are much alike, therefore, both including many areas of rugged relief where dissection is thorough, both being underlain by shales, and both including imperfectly weathered soils consisting mainly of disintegrated shales and clays, due in part to rough relief, in part to the heavy texture of the material, and in part to both conditions. In many places the shales are more or less salty, so that incipient Solonetz development is prevalent.

Three isolated mountain areas lie in the Great Plains of Montana north of Missouri River. The largest, the Bear Paw Mountains, covering an area of about 500 square miles, lies south of Havre; the Little Rocky Mountains, covering about 100 square miles, lie about 30 miles south of Dodson; and the Sweet Grass Hills, somewhat smaller in area than the Little Rockies, lie on the Canadian boundary, mainly within the United States north of Shelby. Each area interrupts the continuity of the Great Plains soils around it. Most of each area is shown on the map as rough stony land, without any attempt to designate the character of the soils. In the two larger areas (the Bear Paw and Little Rocky Mountains), Podzolic soils occupy the higher parts, but extremely small areas have a normally developed podzolic profile because of the steepness of the slopes. Smooth belts around each area and within the outer boundary include dark-colored soils, in every case darker than the Great Plains soils near them. Because of the abrupt rise of each of the mountainous masses from the surrounding plains, no well-defined series of belts, representing all the gradational soil belts from Podzols to Brown or Dark-Brown soils of the surrounding plains, extend around them. Each area is surrounded by a more or less continuous belt of soils darker than the plains soils. In practically all cases these dark-colored soils have developed on gravelly fans, built up by mountain streams. They are shown on the soil map as members of the Daniels series but in detailed mapping have been differentiated on the basis of minor features into several series. In general character they are like the Daniels soils. One area in the Sweet Grass Hills border, derived from glacial drift, is shown as Williams.

The Dark-Brown soils of the smooth uplands south of the glacial boundary, in Montana, the Dakotas, Wyoming, Nebraska, Kansas, and Colorado, covering a large area in which practically no field studies other than incidental examinations of profiles and the collection of samples for analytical work have been completed, are shown on the map as Rosebud soils. (Fig. 46.) This series of soils was defined on the basis of the characteristics of the soils in western Nebraska. They are Dark-Brown soils having essentially the same color and other profile characteristics as the Scobey soils, differing from the latter soils in their derivation from material accumulated by the weathering of the country rock which is not uniform within the whole area shown on the map as Rosebud. It is well known that the soils are not uniform over this region, but because of lack of specific information they are included in one series group. Southward the Rosebud soils change gradually to light-colored Chestnut-Brown soils and finally into dark reddish-brown soils. They are shown on that part of the soil map covering western North Dakota as an almost continuous body, broken only in small areas. The continuity is owing mainly to the smoothness of

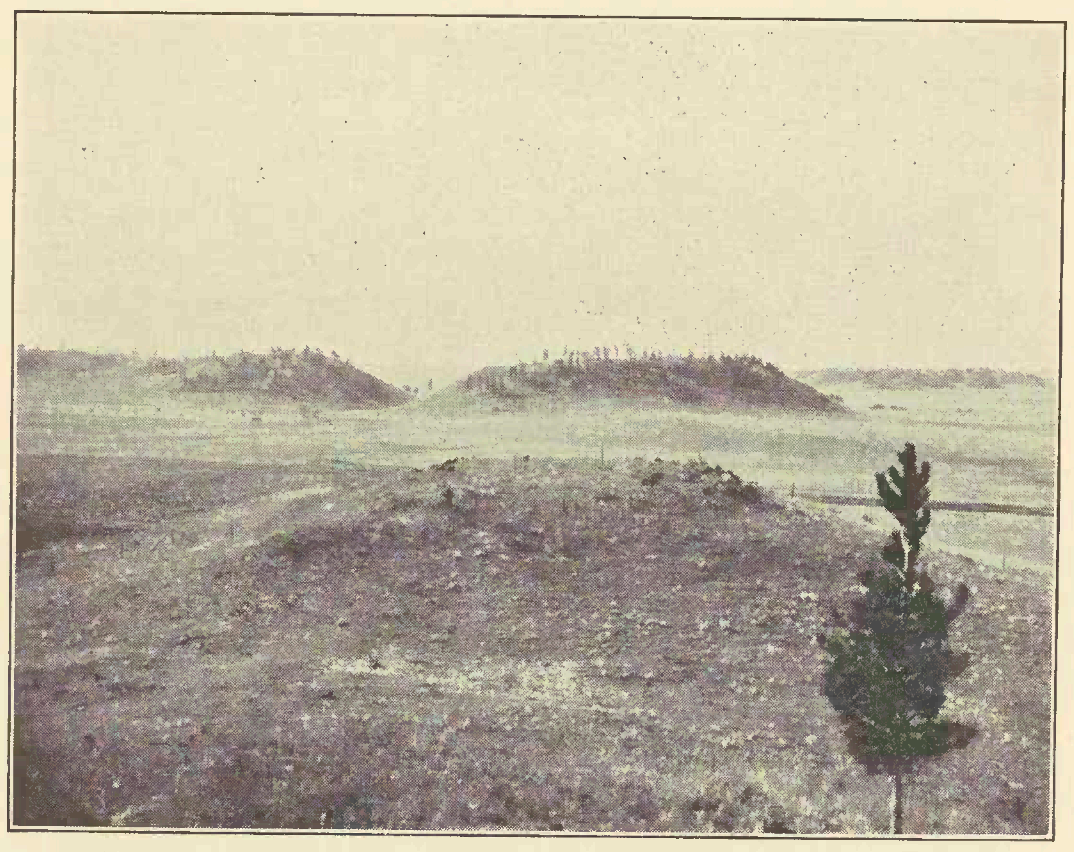


FIGURE 46.—Dark-Brown soils, showing burned shale mesas, in southeastern Montana.

the region over which they occur and to the absence of information regarding details of soil character. In general profile characteristics they are similar to the Chernozem soils, but the color of the surface soil is dark brown instead of black and the thickness of the dark-colored layer is less than that of the black surface layer of the Chernozems. The zone of carbonate accumulation is, in the mature soil, well developed and, as a whole, lies a little nearer the surface than in the Chernozems.

Another important difference, however, between the Rosebud soils and the Chernozems, especially in the central and southern parts of the areas of both groups, is the presence of highly developed granulation in the latter and its absence in the former, taken as a whole. As mentioned before, in North Dakota the structure of the Chernozems is not well developed. In this case, therefore, this difference between the latter and the Rosebud soils is not noticeable. Farther southward, however, the granulation is very noticeable and is especially well marked in central-western Kansas, and it is noticeable also in western Nebraska.

In western Kansas the Rosebud profile is characterized by a loose mulchlike surface layer of comparatively coarse material which is subject to shifting by the wind and is probably the product of continual wind shifting. This layer is rarely more than 2 or 3 inches thick. It is underlain by a 6- or 8-inch firm, structureless, seemingly heavier horizon containing the great mass of the grass roots constituting the layer which gives the soil its dark color. This layer, in turn, is underlain by a lighter colored horizon which may have prismatic structure, breaking on exposure into vertical prisms about an inch in diameter. This horizon ranges up to about a foot in thickness and is underlain by the zone of carbonate accumulation.

Throughout the entire area of their occurrence the Rosebud soils have developed from the underlying geological formations consisting mainly of Tertiary deposits. They represent the mature soils of the region in which they occur and are found, therefore, on the smooth areas. In a north-south belt across western North Dakota the continuity of the Rosebud soils is broken by a belt of badlands about 10 miles wide. West of this lies a relatively narrow belt of smooth relief. Extending westward beyond the Montana boundary and covering a large area in southeastern Montana is a large area of dissected plateau in which the dissection is relatively deep and rather thorough, but because of the geological structure the original plateau surface remains intact along the watersheds between the streams. The Rosebud soils, or, at least, Dark-Brown soils, lie on these watershed belts. Whether they will be identified in detailed mapping as Rosebud soils when this area is taken up for detailed mapping is not known, but these soils are identical in their broad features with the Rosebud soils.

Another area of Dark-Brown soils lies in Montana between the Missouri and Yellowstone Rivers. In this area the relief is smoother than in the southeastern part of the State, and therefore the distribution of the soils is more continuous. Along the streams in this region in general, not only in southeastern Montana but in the central part of the State and in northeastern Wyoming, especially along the Musselshell River in Montana, the map shows badlands. This merely means that between these belts of smooth country, covered with Rosebud soils, there are relatively important belts of country so thoroughly dissected that no soil approaching maturity has developed. It is not a region consisting entirely of exposed country rock, but it is covered with loose material which serves as a soil and supports a moderately good grass cover; but no soil profile has developed and the character of the material varies in its details with the character of the underlying rock. It ranges widely in texture but is predominantly heavy and similar in general characteristics to the Pierre soils.

Western South Dakota is geologically very different from western North Dakota. Western North Dakota is underlain by beds of sandy shales and thin sandstones, which furnish material of such a character that the development of a soil profile proceeds at a relatively rapid rate. In western South Dakota, east of the Black Hills and extending around the Black Hills into eastern Wyoming, is a large area of country underlain by Pierre shales. Like fine-grained shales in general, they disintegrate very slowly, and when disintegrated and decomposed, the material supplied is so heavy and so impenetrable to the influences of weathering that soil profile development proceeds very slowly. Throughout a large part of western South Dakota, therefore, especially south of a belt 50 miles wide along the North Dakota boundary, the soils are immature, or have developed into what we may describe as soils without normal profile. These shales are known to contain a small amount of salts, and because of the heavy texture of the material furnished by their disintegration the salts do not leach rapidly. Probably because of the presence of these salts a profile has developed on the smooth uplands containing a hard, heavy, tough, intractable clay layer at a depth ranging from 12 to 20 inches from the surface. The surface soil is dark colored, assuming the general characteristics of the belt in which it occurs.

The zone of carbonate accumulation is not noticeable, presumably because sufficient time has not yet elapsed for its accumulation in material in which the rate

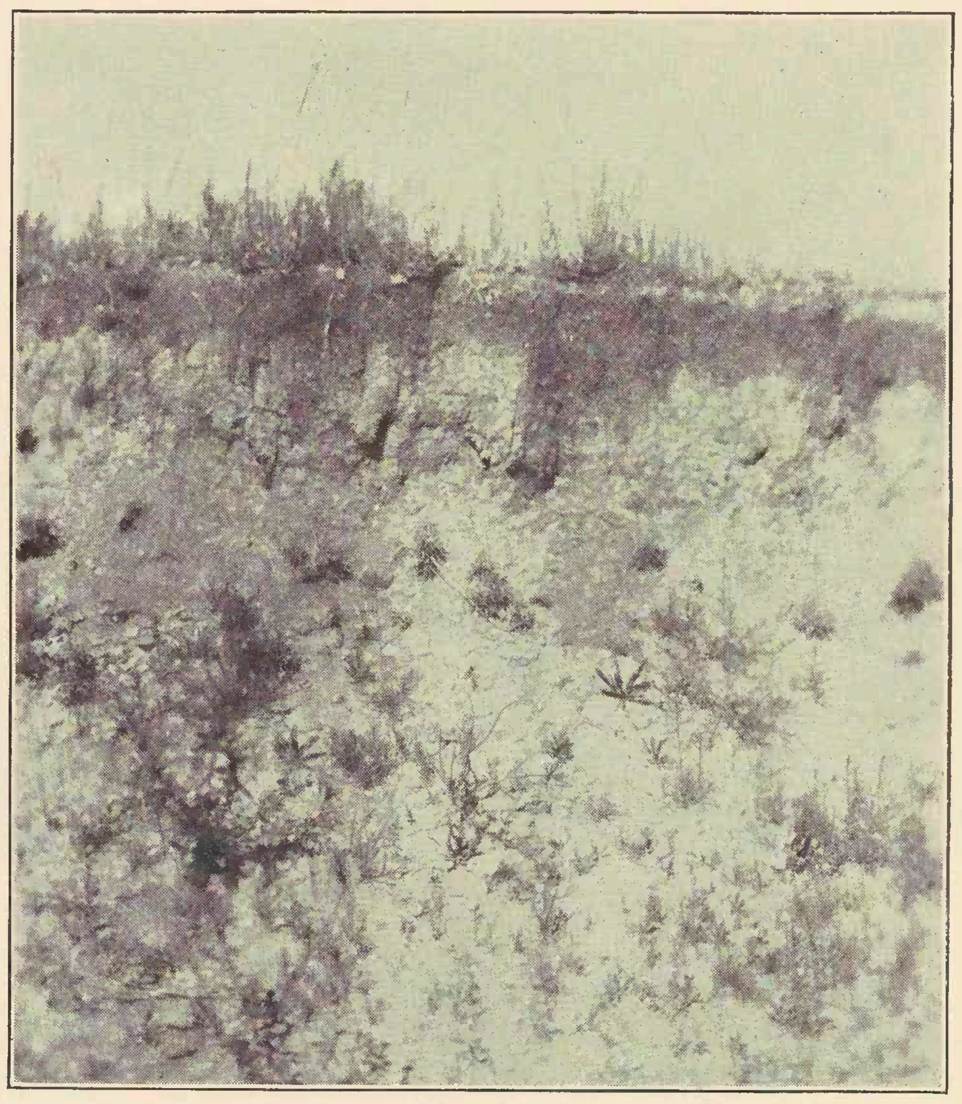


FIGURE 47.—Profile of a Brown soil, near Fort Benton, Mont.

of soil development is so slow as in this. The heavy layer may be designated as a Solonetz, or at least a Solonetzlike layer. In some places it is so fully developed that it causes a certain amount of water logging in the layer immediately above it and causes the development of a gray layer between the surface horizon and the Solonetzlike layer. These soils have been identified temporarily as members of the Dawes series; but as no detailed mapping has been done in the area, this identification is not absolutely certain.

In the extreme southeastern part of western South Dakota, lying immediately west of Missouri River and north of the Nebraska boundary, is an area of Daniels soils. A similar soil is mapped in a narrow belt surrounding the Black Hills in the western part of the State, the greater part of the Black Hills being mapped as rough stony land, although within them are considerable areas of moderately well-developed soils, some of which are known to be Chernozems, whereas others, belonging to the various members of the Pedalfer group, are known to occur. In the mountain regions of the West, where the soils around the mountains consist of the lighter colored members of the Pedocals, a succession of soil belts occurs from the base upward in which the soils become progressively more and more podzolic. Where the mountains rise from the desert, the first belt above the desert consists of Brown soils succeeded by a belt of Dark-Brown soils, and this in turn by Chernozems, while still higher the Gray-Brown Podzolic soils are found. In most cases, however, the material is not allowed to lie in place long enough for normal profile development to take place, so that in the actual fact, within the United States a well-defined succession of these belts rarely occurs.

The soil map shows the extension of the Rosebud soils in southeast Montana and northeast Wyoming westward to the foot of the Big Horn Mountains. It shows also a very narrow belt of Daniels soils lying immediately beneath the eastern foot of the mountains. In western Nebraska and eastern Wyoming the Rosebud soils are also shown in an almost continuous area westward to the foot of the Laramie Mountains. North of the north end of the Laramie Mountains and southeast of the Big Horn Range is an area mapped as Otero soils. This is the name given to the Brown soils of the central part of the Great Plains area. This area in Wyoming, an area on Platte River in the vicinity of Denver, and another on the upper Arkansas River, extending from the foot of the mountains west of Pueblo eastward, constitute the Otero soils of the Great Plains region. The soil series was created in order to cover the normally developed upland soils occurring in the Arkansas River Basin in the vicinity of Pueblo. The series includes soils with the usual loose, or mulchlike, thin surface layer and an underlying, firm, structureless layer, or horizon, brown rather than dark brown in color, and this, in turn, is underlain by looser material which may or may not break into prisms on exposure.

The zone of calcium-carbonate accumulation lies at a depth of less than 2 feet. It will be noticed that these three important areas of Otero soils occur, two of them at low elevations, one along Arkansas River and one along Platte River, whereas the third, or the one in eastern Wyoming, is an eastern extension of the desert or very dry region of central Wyoming. The northern, or Wyoming, area lies also in the upper basin of North Platte River and may also be regarded, therefore, as occurring in a lowland area. The Arkansas and Platte River belts in eastern Colorado are connected in their eastern part, their western parts being separated by an eastward projection of a highland area extending eastward from the foot of the Rocky Mountain Range between Denver and Colorado Springs, in which the soils have been mapped as members of the Rosebud and Daniels series.

The Rosebud soils have been mapped in a semicircular belt around the rim of the area and the Daniels in the central part. The reason for the extension of the Rosebud soils westward across Nebraska to the foot of the mountains in eastern Wyoming lies in the rather high elevation of the plains in this area.

The central Wyoming belt of Otero soils extends southward west of the Laramie Range and occupies the greater part of the Laramie Basin. It has been extended on the soil map into the region of central Wyoming along the Union Pacific Railroad and extends southward into a high-plains region of northwestern Colorado surrounding Craig, Colo. The high mountain basin known as North Park in north-central Colorado, lying immediately south of the Saratoga Basin, is also occupied by the Rosebud soils.

The range of mountains constituting the Rocky Mountain front on the international boundary in western Montana is the boundary between an almost unbroken stretch of grassy plains extending eastward for hundreds of miles and a stretch of forested mountains to the west. It extends southward as a continuous range almost to the Idaho-Montana boundary. South of the latitude of Great Falls it does not constitute the boundary of a great stretch of unbroken plains to the east and a mountainous area to the west, but east of a narrow lowland belt lying at the foot of the main range lie a number of isolated ranges varying in length from a few miles to a hundred miles in the case of the Big Horn Range in Wyoming. These may be looked on as outliers of the Rockies, lying out in the Great Plains. Between these ranges lie lowland belts which may be considered outliers of the Great Plains, in some of which moderately dark colored soils have developed under rainfall somewhat higher than that on the neighboring plains (Fig. 47). One such area of considerable size is the Judith Basin and another the Gallatin Valley. In the latter the soils are dark in color near the surrounding mountains only and light in color in the interior of the basin. In other and probably a majority of cases, these valley basins are drier than the neighboring Great Plains. It is among these isolated mountain areas, including those in Yellowstone National Park, that the several rivers which finally unite to form the Missouri have their source.

These lowland belts, however, are not river valleys but are structural lowlands which range from a few miles to more than 40 miles in width and consist of valley plains bounded by mountain ranges. Within the mountain masses and ranges there are also a great many areas of high plateau surfaces, smooth enough for the development of at least a subnormal soil profile, and most of these plateau surfaces are covered, or were covered under natural conditions, by grass. They also, therefore, may be regarded as Great Plains outliers. With few exceptions they all lie within areas of low rainfall, the surrounding mountains causing the precipitation of most of the moisture, the valleys of lowland belts receiving a small amount. They receive enough, however, to allow the growth of some grass, but the density of the grass cover, and therefore the darkness of the soils, is different in different valleys.

As a general rule the high grassland plateaus within the mountain masses have dark-brown soils, and the border belts of the valley basins adjacent to the mountains have similar soils. The interiors of the valley basins, however, are covered, as a rule, with Brown soils. Some soils on the high plateaus belong with the Chernozems. Recent work has shown, for example, that the soils in the east-west belt along the northern slope of the Little Belt Mountains, southeast of Great Falls, have developed a good Chernozem profile. (See p. 77.) The lowland belt lying immediately east of the Rocky Mountain front, from some 50 miles north of Helena southward to the vicinity of Three Forks, and that lying along Missouri River, from Three Forks to the vicinity of Wolf Creek, contain Brown soils, having developed under low rainfall. The soils in most of the valleys south and southwest of Three Forks, as well as those in the southern part of Gallatin Valley, are in part Dark-Brown soils and in part Chernozems, the latter occurring only in the upper end, and therefore in the higher parts of these lowland belts. The western part of Gallatin Valley is covered by Brown soils. Eastward, however, the soils are darker and in the vicinity of Bozeman and thence eastward to the foot of the bounding range seem to have a profile approaching that of the Chernozems. The soils in none of these lowland belts south of Great Falls have yet been identified as to series, and the only information we have is what has been gained as a result of rapid observation in traveling across the region in the normal progress of the soil survey work.

All of these lowland belts are structural, so far as their geological origin is concerned, but the existing soils have developed largely, if not entirely, from material carried into them from the adjacent mountain ranges after they were formed as structural lowlands. The soils have been derived from water-laid materials which range widely in character, depending on the character of the material of the adjacent mountain slopes. In detailed mapping they will be differentiated into a large number of series, but enough is known of them to warrant placing them in the great groups as indicated.

North of the latitude of Great Falls the soils along the Rocky Mountain front constituting the series of narrow belts of the main Pedocal groups, as has been indicated, have also developed from water-laid material. After the uplift of the Rocky Mountains, streams flowing from the mountains onto the Great Plains carried loads of coarse material, consisting mainly of gravel, which were deposited as a great apron spread out on the Great Plains from the mountain front. This apron was deposited,

presumably, in Pleistocene time, but the identification of the geological age of the deposits is not vital to the interpretation of the character of these soils. Since its deposition this great apron has been deeply dissected, the depth of dissection being greatest along the Rocky Mountain front and decreasing eastward. As a result of the dissection the apron has been cut into a number of isolated tablelands with more or less perfect tableland surfaces separated by relatively broad valleys. Because of the mesalike form of these areas and belts, the region, taken as a whole, is often designated as the bench belt of the western Great Plains in Montana. In fundamental characteristics these benches, however, do not differ geologically from the material filling the valleys farther southward, which may be considered as southward extensions of the bench belt, although dissection in these southern lowland belts has not been so great, and the lowland belt surfaces are continuous lowlands rather than isolated benches separated by valleys.

As already explained, the soils of these benches differ in color according to their distances from the Rocky Mountain front. Immediately along the front they are black, eastward they become lighter in color, and in the vicinity of Cut Bank, where the belt is broadest, their color approximates that of the Joplin soils. They belong, therefore, in the Brown soil belt.

The bench belt may be extended eastward a short distance south of Great Falls along the north front of the Little Belt Mountains, though the greater part of this region is made up of material accumulated by the decay of country rock in place or by processes other than the deposition of gravel. The largest continuous, or presumably continuous, area of the gravel deposits within the State begins in the vicinity of the western boundary of Judith Basin County and extends eastward entirely across the county and for a considerable distance into Fergus County. This area, made up mainly of bench land or of smooth land underlain by thick deposits of gravel, is at least 50 miles long and has an average width of about 25 or 30 miles. It is an area surrounded by a discontinuous belt of mountains. Along the southern part of the belt the Big Snowy Mountains extend as an almost continuous range along the whole length of the basin. Northeast of the eastern end, lying south of the village of Roy, is an isolated mountain area, and a smaller one lies a few miles to the west. Thence westward the northern boundary is open until the southwestern part of Chouteau County is reached, where it is occupied by the Highwood Mountains.

This series of surrounding mountains seems to constitute the physiographic environment which has produced local climatic conditions, especially those of rainfall, which are responsible for the fundamental character of Judith Basin soils so far as their true soil characteristics are concerned. The gravel deposits have had nothing to do with the development of their characteristics as soils, other than such subordinate characteristics as texture which has been inherited from the character of the gravels rather than caused by their existence. These soils are dark in color and are predominantly members of the Dark-Brown soils group, but in the periphery of the basin along the mountain bases the rainfall is high enough to have caused the development of a Chernozem profile. Such profiles are especially noticeable in the vicinity of Judith Gap and in a small region east of Lewistown. It is apparent also, although because of lack of detailed surveying specific knowledge is not at hand, that a Chernozem belt lies along the north foot of the Belt Mountain Range. As already mentioned, it is known that such a belt lies north of the Little Belt Mountains immediately southeast of Great Falls.

The Judith Basin soils are mapped as Daniels. In soil characteristics they are essentially identical with the Daniels soils, although the gravel are not absolutely identical in character with those of the Daniels soils, and the geological periods during which they were deposited were not necessarily identical. The dark-colored surface soil is rather thin in most parts of the basin.

The mountains surrounding the Judith Basin have not only been important factors in determining the character of the soils within the basin, but they have influenced the development of the soils outside of the basin in the Great Plains region adjacent to the mountains. South of the Big Snowy Mountains and the Belt Range the soils of the Great Plains are dark in color immediately along the bases of the mountains but become lighter with distance from the mountain bases. The soils in a belt extending southward almost to Musselshell River, like those within the Judith Basin, have been developed from gravel deposits. The gravel were spread out in the form of alluvial fans from the southern slopes of the mountains presumably at the same time that the gravel within the basin were spread out to the north. The belts of dark-colored soils, however, are much narrower in the Great Plains south of the mountains than within the basin. Similar belts of soils lie east of the main part of the Judith Basin and also on the north. In fact, the area of Scobey soils, already described as in the region south of Fort Benton, may be considered as a part of this belt of dark-colored soils lying on the Great Plains surrounding the enclosing mountains of the Judith Basin.

In the Great Plains region, south of Musselshell River and north of the mountain spurs which run northward from the Yellowstone Park mountain masses, the soils are mainly members of the Brown soil group. A narrow belt of Dark-Brown soils lies around the foot of the Crazy Mountains, and Dark-Brown soils lie as a border along the mountain front south of Yellowstone River east of Livingston. They are shown on the map mainly as members of the Rosebud series. No detailed mapping has been done in this region, however.

The western or mountainous part of Montana is so largely mountainous that it is shown on the soil map (pl. 5, secs. 3 and 4) mainly as rough stony land. This does not mean that there is no soil or vegetative cover in such a region but that the soils are shallow, consisting mainly of disintegrated rock or having a very imperfectly developed profile changing from place to place with the change in the character of the rock, since, as is well known, the character of the latter determines largely the character of young soils. The vegetation in the mountains is forest, mainly fir and western yellow pine, and the soils are Podzolic. In one north-south lowland belt several miles in width, the soils have developed the normal profile of the region and belong mainly to the Brown soil group with smaller areas of Dark-Brown soils. This lowland belt, known as the Flathead Valley in the northern part of the State and Bitter Root Valley in the southern part, is not occupied by any one river, but is a continuous lowland. The southern end is occupied by Bitter Root River and the northern end by Flathead Lake and by Flathead River for a short distance south of the lake. The belt is crossed by Clear Fork of Columbia River at Missoula, the stream entering it at that city and following it for a few miles before turning again to a northwestward course. The soils, like those in all mountain valleys of the West, are dark around the outer rim of the valley and lighter in color in the interior. In the Bitter Root Valley the east side has the darker soils. The soils in the Flathead part of the valley are dark colored, especially on the eastern side. Taken as a whole, however, they are members of the Brown soil group. Considerable areas of the southern end of the Flathead part of the valley are marked by the presence of a great number of "alkali" (Solonetz) spots. The darker colored soils in the mountain valleys of Montana generally are shown on the soil map in this Atlas as members of the Bridger series, and the lighter colored humid soils are shown as members of the Springdale series. In detailed mapping they will be separated into a large number of series.

The Snake River Plains of Idaho are a part of the Great Basin, and the soils are mainly members of the various desert soils of this large physiographic region. Around the eastern border, however, the rainfall is higher and grass growth has developed a belt of soils darker than those in the desert. These soils lie not only along the eastern border of the Snake River Plains but also occupy a number of outlying lowland belts, one of which is the valley of Great Bear Lake in southeastern Idaho. In these places the soils, except certain poorly drained areas which have not developed a profile, are mainly dark-colored soils belonging mainly in the Dark-Brown group but to a relatively light colored phase of that group. They are mapped as members of the Ritzville series. This series of soils was established in the State of Washington, but the relatively dark colored soils of the eastern part of the Snake River Plains and its outliers in Idaho seem to belong to the same series. The Ritzville soils have developed from loess in both Idaho and Washington.

At a somewhat higher altitude in the same region, occurring in rather narrow belts along the upper borders of the intermountain valleys, especially along the upper course of White River in the northwestern Colorado region, a dark-colored soil, almost as black as a Chernozem and probably belonging to this group, has been mapped as Meeker. This soil has not been identified in detailed soil mapping, but it is known to occur in limited areas. It seems to have developed under a rainfall of about 20 inches and is covered partly by grass but mainly by Artemisia and scrub oak. The latter occurs in small patches scattered here and there throughout the area, giving a parklike expression to the landscape. Similar soils occur in many places along the western side of the Colorado range, and a belt of such soils covered with about the same kind of vegetation is shown on the map in a rather large area extending northward from west-central New Mexico, across northeastern Arizona, and into southeastern Utah. The soils in this belt lie to the east of the Otero belt which occupies the basin of Little Colorado River from the New Mexico boundary northwestward practically to the Utah boundary. These soils are rather widespread in northwestern New Mexico and northeastern Arizona, as well as southeastern Utah and adjacent parts of Colorado. They are important soils in the upper San Juan River region of southwestern Colorado and adjoining parts of New Mexico.

An attempt has been made in constructing the soil map to cover with the Meeker soils all known areas of dark-colored soils lying around the mountain bases of the high plateaus of the Southwest, especially in the region where the vegetation consists of oak chaparral. They constitute the soils developed under a higher rainfall than that under which the Otero soils have developed, especially the Otero soils as they are mapped in the high plateaus of northern Arizona and New Mexico. It is well known that the Otero soils in this region have a less well developed grass cover than the Otero soils in their typical area of the upper Arkansas Valley in the Pueblo region, yet taken as a whole they are similar. In this connection it should be borne in mind that the mapping in all of this region is based on very general knowledge obtained in the course of traveling across the country in the progress of the soil survey work, but none of it has been obtained by detailed study of the soils of this region. When the soils of the region have been studied and mapped in detail, it is probable that the pattern of soil distribution will be entirely different from that shown on the soil map in this publication.

Another soil series shown on the map, associated more or less intimately with the Meeker soils in New Mexico and Arizona and to a slight extent in Colorado, has been designated as the Deschutes series. These soils occur either near the watersheds between the streams flowing northward or northeastward to the Colorado and those flowing southward into Gila River or Rio Grande. They occur on the high plateau of this region and in most cases near its southern boundary. They are somewhat darker than the Meeker soils and have developed under a more continuous grass cover. They occupy the shallow grass-covered basins in the plateau of New Mexico in the Magdalena and Datil region and on the southern edge of the plateau in the vicinity of Springerville, Ariz., and eastward into New Mexico. Still farther west they occupy isolated areas in the vicinity of Snowflake and Shumway in Arizona and larger areas farther west along the southern part of the plateau south of Williams and Flagstaff.

At a still higher altitude, in the same region, where the vegetative cover consists of timber but the rainfall is not sufficient to allow the development of a dense timber cover, the soils, being light in color and the profile imperfectly developed, are shown on the map as members of the Encina series. These soils have not been studied in the regular field service of the Soil Survey, and their definition and distribution are based on very general information only. The color seems to be somewhat darker than that of the true Podzolic soils, but they seem to have been deprived of such carbonates as were present in the parent material and no accumulation of carbonates seems to have taken place. Their distribution, as shown on the map, has been determined to a considerable extent on the basis of elevation above sea level and other geographic factors. Such soils are known to occur, and the general geographic environment causing their development is known in a very general way, but their distribution in mapping is the result of an attempt to interpret the distribution of the environment rather than of the soils themselves. These soils are associated with another group, known as the Melbourne series, occurring mainly, however, in Oregon, whose characteristics were determined by detailed mapping under Oregon conditions. It is well within the range of possibility that the latter soils do not really occur in any part of the area of Encina soils as shown on the map. The Melbourne series is well established, but has been identified in the detailed field study of soils in the Pacific Northwest only, and has been confined to slightly dark colored Pedalferlike soils developed under combined open woods and a grass cover, from material accumulated by the disintegration of sandstones.

In the San Luis Valley of the upper Rio Grande in southern Colorado, a considerable part of the soils has been mapped as belonging to the Onyx series. Little is known about these soils, except that they have developed under a grass cover and are not well drained. They are dark colored and have been subjected to relatively high ground water.

Another soil, occurring mainly in the valleys of Utah, has been mapped as the Hyrum. The Hyrum soil series was established in Cache Valley, Utah, and consists of dark-colored soils developed from water-laid material deposited in ancient Lake Bonneville. These soils are dark because of their occurrence around the rim of the Cache Valley Basin, in situations where, because of their nearness to high mountains, the rainfall has been sufficient during the progress of their development to cause a vigorous growth of grass and other shallow-rooted vegetation. Soils of the same general character occur in the valleys of the Wasatch Range in Utah over considerable areas and in important areas in the Flathead Basin and other similar mountain basins of Montana. They are not all included in detailed mapping as members of the Hyrum series, but they are, in general, comparatively dark colored soils and have been developed from water-laid materials under the influence of a relatively high rainfall. In the larger basins, such as the Roosevelt Basin in northeastern Utah, soils with the general characteristics of the Hyrum occur more abundantly around the rims of the basins and lighter colored soils are in the interiors. Soils of the same general character occur in the small Vernal Basin in northeastern Utah. It is well known also that dark-colored soils occur in relatively smooth areas on high plateaus within the Uinta Mountain region of Utah. They have never been studied, and the details of their characteristics are wholly unknown. Their presence has been determined mainly by the fact that they are used in places by the Mormon farmers of the Vernal Basin for the production of dry-farmed wheat.

A similar area of dark-colored soils, used also for the production of wheat, lies in southeastern Utah in the Monticello region. This is a watershed region, one from which drainage radiates northward, westward, and southward, and it attains such an elevation as to cause a rainfall high enough to have developed sufficient vegetative cover throughout the period of soil development to give the soils a dark color.

The soils along the top of the Tavaputz Plateau bounded on the south by the Book Cliffs, a conspicuous topographic feature lying just north of the Denver & Rio Grande Western Railroad in a long stretch extending from some 20 miles east of Grand Junction, Colo., westward to Price, Utah, in a narrow belt, are dark colored, although they are covered with brush. They are almost dark enough to be mapped as Chernozems and have a well-defined zone of calcium-carbonate accumulation.

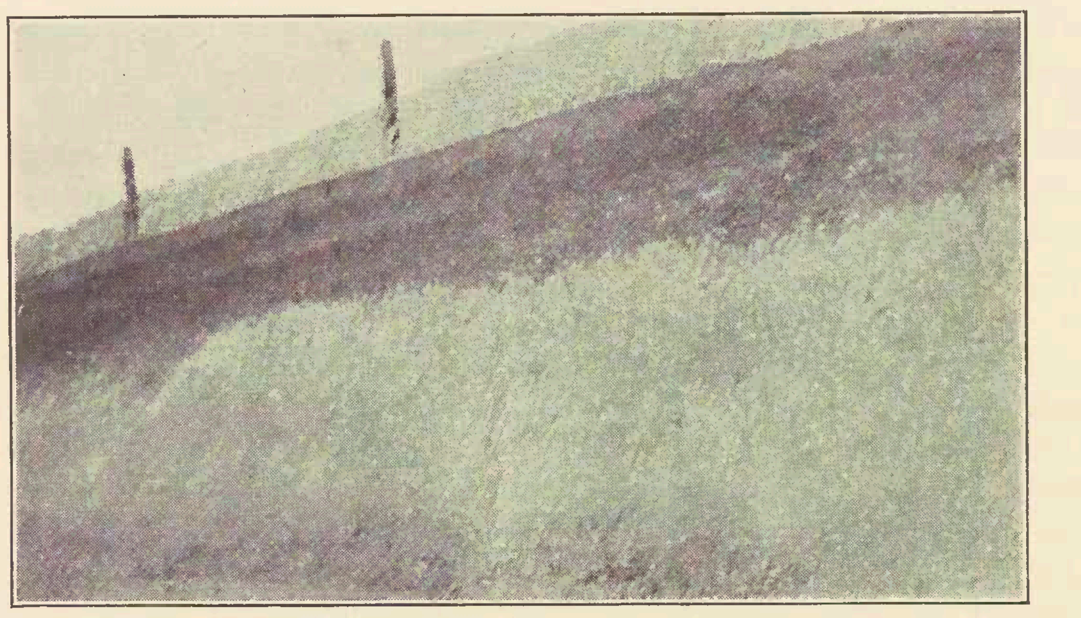


FIGURE 48.—Profile of Palouse silt loam, near Pullman, Wash.

The width of the belt, however, is very slight, and north of it the soils soon become light in color, similar to the light-colored members of the Pedocal group.

Detailed soil mapping, or even soil mapping of a definite kind on any scale, has not been attempted in the Great Plains of eastern New Mexico. It is known that the soils are typical southern Great Plains soils. They include darker colored and lighter colored groups and have developed under grass or grass and brush cover. The darker colored members lie on comparatively smooth surfaces, have a relatively well developed zone of lime-carbonate accumulation, have developed on material of relatively recent geological age, probably Tertiary, and have attained maturity of development under the conditions existing in the region. They are about as dark as the Dark-Brown soils. They are darker than the Brown soils of the Otero series and are shown on the map as members of the Springer series. This is a series which has not been officially established in the detailed mapping of the Soil Survey, but the soils are known to cover the greater part of the Great Plains of northeastern New Mexico, especially that part stretching along the mountains and extending eastward for a distance of about 50 miles. They extend northward also beyond New Mexico into the region of the Trinidad Mesa in Colorado and northeastward to the high plains of Texas. These soils are somewhat darker than those lying immediately east of them in New Mexico and Texas, because that part of the plains lying near the mountains receives higher rainfall than the part farther away. This is merely an expression of the same relationship shown throughout the western part of the United States, the simplest and clearest illustrations of this relationship consisting probably of the Rocky Mountain border belt and the Judith Basin in Montana.

The Springer soils extend southward from the northern Panhandle of Texas in a narrow belt to the northern boundary of the western extension of the Edwards Plateau a few miles south of Midland, Tex. Throughout this belt they are sandy, the sand layer being thicker than the solum over an important part of the belt. The sand is underlain by red clay containing abundant calcium carbonate. The sands are reddish below the dark-brown or dark reddish-brown surface soil. In the comparatively small areas, where the soils are not sandy, they are shallow, overlying a limestonelike rock consisting of the indurated zone of carbonate accumulation. This indurated horizon constitutes the hard bed in the escarpment forming the western boundary of the high plains in southeastern New Mexico.

South of the southern end of the sandy Springer soils in Midland County, Tex., the soils are heavy, shallow, dark brown, and underlain by limestones and calcareous shales. These soils and the shallow dark-brown soils north of the Springer sand are members of the Reagan series. They, especially those south of Midland, are young soils, the carbonates (parent rock) in the surface horizon not yet having been removed. Another area shown on the map as Reagan soils, but in which the identification is based on very general information only, lies on the ridge between Pecos River and Rio Grande in New Mexico. On top of this ridge, in an area a few square miles in extent, where the rainfall is sufficient to cause the growth of a yellow-pine forest, the soils are mapped as Kaibab. These soils are members of the Gray-Brown Podzolic group, but have been differentiated from the soils in other parts of the West and Southwest, developed under a cover of yellow pine, because of their development, in New Mexico and in a few other localities where the Kaibab soils are shown on the map, from limestones.

A Brown soil developed from limestone material, belonging in the same great group as the Otero soils, lies along the slopes of this ridge below the level of a belt covered with a thin stand of yellow pine, in which the soils are included with the Encina soils. This soil is reddish brown and shallow. It occurs in a number of localities in New Mexico and in southern Arizona, especially along the international boundary east and west of Douglas, Ariz. It is usually associated with the Encina soils in this region, but the latter have a redder color here than in the more elevated situations which they occupy in Colorado and adjoining States. They are associated with a group of still darker soils identified as members of the Elgin series. The latter have developed under a comparatively light grass cover. They occur in most perfectly developed form in the plateau region lying from 50 to 60 miles south of Tucson, Ariz. They also extend northward along the watershed between the Santa Cruz and San Simon Rivers as far as the line of the Southern Pacific Railroad immediately west of Benson, Ariz. They are also well developed in the vicinity of Bisbee, Ariz., and mark the southern border of the desert region of southern Arizona and New Mexico and the beginning of a high mountainous plateau country which apparently occupies a considerable area of northern Mexico where the rainfall is higher than in the basins of the Gila and Salt Rivers, Ariz. Soils of similar character, although not shown on the map, occupy the higher parts of all the intermountain plains of this southern desert region and occur in a number of places on the southward slope of the high plateau of northern Arizona.

A large area of Otero soils lies along the upper Pecos River and extends northeastward into the western part of the panhandle of Texas. It occupies in part a rather thoroughly eroded region on which the grass growth is not vigorous. That part of the soil lying above the zone of carbonate accumulation is thin, in many places only a few inches thick, and in many places the fine material overlying the lime zone seems to have been derived from the decomposition of the limestone, consisting in much of the area of indurated caliche material. This belt extends southwestward to the Gray Desert soils of the Rio Grande basin. Other areas of Otero soils are shown on the map in a number of localities. No field studies have been carried on

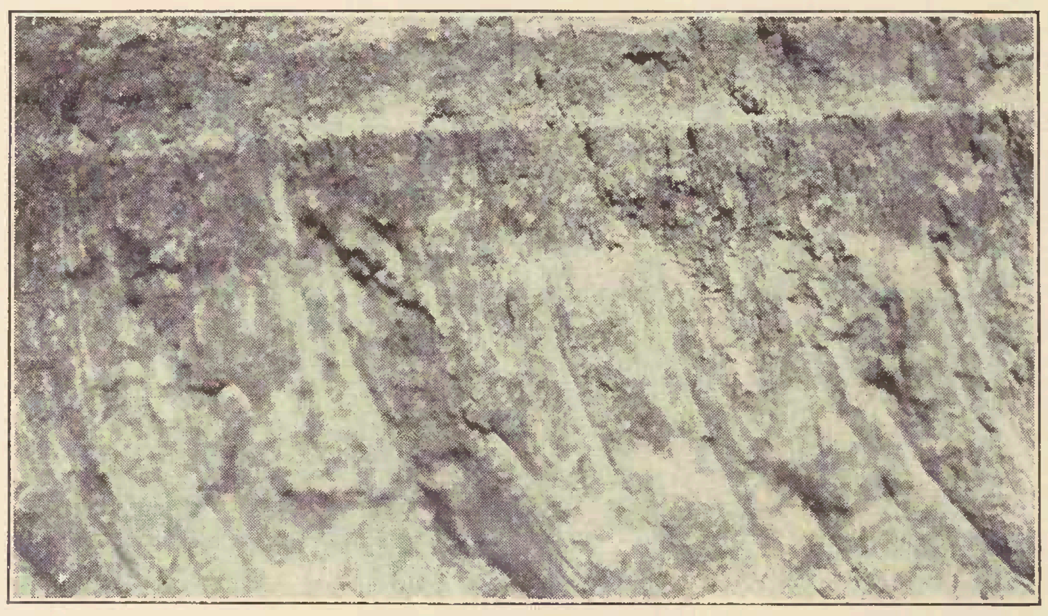


FIGURE 49.—Profile of Palouse silt loam, near Pullman, Wash., showing Solonetzlike horizon with overlying gray zone and underlying carbonate zone.

in this region, and the differentiation of these soils into units, as well as their distribution, is based on very general knowledge only and can not be considered, so far as details are concerned, much better than guesswork.

On the slopes of the escarpment rising from the desert of southern Arizona and New Mexico to the high plateau of the northern parts of these States, the Aiken soils have been mapped in two or three localities. These soils are humid soils belonging typically in the Pacific coast region of Oregon and the humid parts of California. They are young to submature soils, so far as profile development is concerned, are red or somewhat red-brown in color, and are derived from material accumulated by the disintegration of basalt and other dark-colored igneous rocks. In this region they are immature because of their occurrence on uneven surfaces, but in most of the Pacific northwest they consist of material that, in its accumulation in place, has been subjected to very strong, apparently lateritic leaching. They are Podzolic soils.

THE SOILS OF EASTERN WASHINGTON AND OREGON

A miniature Great Plains area occupies a part of eastern Washington and extends as a fringe southward and westward into Idaho and Oregon, following the northern slope of the Blue Mountains. In extreme eastern Washington and western Idaho the soils are humid soils developed under a rainfall of 30 or more inches, have been subjected to the influences of timber cover throughout their period of development, and have developed a podzolic profile where the material has lain in place long enough for such development. Although most of the region is mountainous, considerable areas of soils belong, apparently, to the Gray-Brown Podzolic group. The soils of the Helmer series, which is rather widely distributed in eastern Washington and western Idaho, and certain other series, from point of view of fundamental soil character, constitute the important members of Gray-Brown Podzolic soils in this area. The true Helmer soils have developed from loess, their parent material being merely an eastern extension into a humid part of eastern Washington and Idaho of a large area of loess occupying most of the State of Washington east of Columbia River.

Westward from the area of Helmer and associated soils, the timber cover disappears, and the soils have developed under grass cover in an environment like that of the Great Plains. The soils are true Pedocals and occupy in Washington a series of north-south belts, each successive westerly belt consisting, a similar relationship to that in the Great Plains, of soils lighter in color than the belt immediately east of it. There is a succession from east to west, therefore, of Chernozems, Dark-Brown, Brown, and Gray soil belts, lying between Spokane and the Columbia River at Wenatchee. The most easterly of these belts is that of the Palouse soils (figs. 48 and 49), constituting members of the Chernozem group. They occupy a belt about

50 miles wide, the eastern boundary at the northern end of the belt lying a few miles west of Spokane and the western marked by a north-south line extending from the junction of Spokane and Columbia Rivers southeastward and thence southward to the vicinity of Davenport. Thence the belt runs southward crossing the Columbia River just west of the mouth of Palouse River and from that point runs south and west parallel to the course of the Columbia, maintaining a distance of a few miles from that stream. These dark-colored soils occupy, therefore, the eastern part of the State of Washington and the higher northward slope, although not the top, of the Blue Mountains in Oregon. (Fig. 50.) They extend into Idaho, entering that State about halfway between Moscow and Spokane and leaving it a few miles south of Lewiston. They occupy a large area in the basin of Clear Water River in the western part of Idaho. The belt is considerably narrower in Oregon than in Washington since it occupies a rather steep slope, the upper part of which extends into a region where the rainfall is too high for the development of true Chernozems and the lower part into a region where the rainfall is too low.

West of the belt of Palouse soils in Washington is a belt of soils shown on the map as Ritzville. This includes in this region, the equivalent of the Dark-Brown soils of the Great Plains. It ranges in width from 15 to slightly more than 20 miles in Washington, but not enough is known of its extent on the Oregon side to warrant making an attempt to show its distribution. It runs parallel to the western or inner boundary of the Palouse soils.

The profile of the Ritzville soils, as well as that of the Palouse, is typical of the soils of the great group to which each series belongs. The Palouse soils are dark or almost black, the dark-colored layer ranging up to 18 inches in thickness, and the zone of calcium-carbonate accumulation is normally well developed. These soils occur in a region of uneven relief so that the zone of calcium-carbonate accumulation has not developed so well as in the Chernozem belt of Kansas or of the Dakotas. It is present, however, and easily recognized. The Palouse soils differ in one important respect from the soils of corresponding texture in Kansas and Nebraska in that they have no granular structure. It is not yet known why this is so, but it is presumably due to somewhat more extensive leaching than has taken place in the Chernozems of Kansas and Nebraska. Presumably these Chernozems are degraded though the other evidences of degradation usually apparent, such as the presence of gray coatings on such soil particles as may be found, are not present. The Ritzville soils, so far as is now known, are well-developed members of the Dark-Brown soils. The Brown soils are shown on the map as a belt of Portneuf soils which occupy a belt lying west of

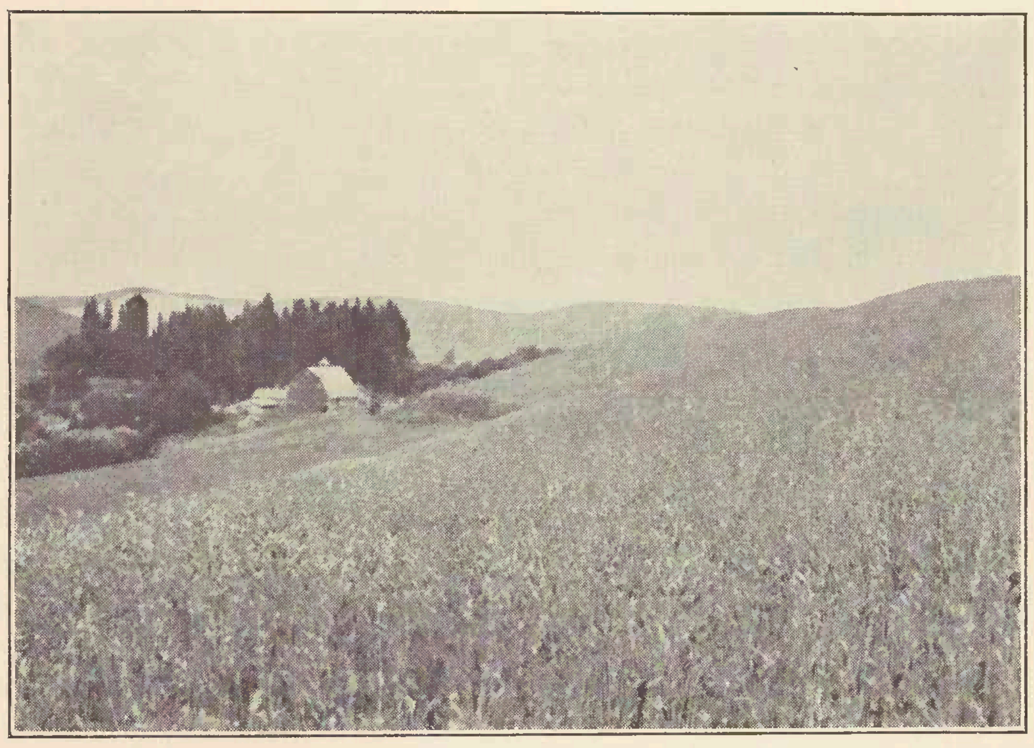


FIGURE 50.—Typical view in region of Palouse soils, near Pullman, Wash.

the Dark-Brown soils, and finally in the great bend of Columbia River from Pasco northward the soils are gray, shown partly as Sand, partly as Quincy soils, and partly as Ephrata. West of this Gray soil area, which marks the area of lowest rainfall, the soils become darker again, owing to increasing rainfall as the mountains are approached. A considerable area is shown as Portneuf, with small areas of Ritzville.

THE GRAY SOILS

Because of the fact that these soils, except in the small areas where irrigation is possible, are practically nonagricultural, little work has been done on them. A few areas have been mapped in the western part of the desert in California, in the eastern part of Utah (fig. 51), small areas in Arizona and New Mexico, and a considerable area in western Idaho. Some work has been done in central Washington and central Oregon. The soils, tentatively at least, placed in the Gray group or, in Russian terminology, the Gray Desert soils, occupy the Great Basin region extending from the foot of the Wasatch Range in Utah to the Sierra Nevadas. They extend northward into Washington, but their extension into Canada has not yet been demonstrated. The greater part of north-central Washington is occupied by low mountains in which the rainfall is a little too high for the development of Desert soils. For all practical purposes, the northern boundary of the large area of Desert soils may be considered the Columbia River in Washington.

Southward from the Great Nevada-Utah area of the Great Basin these soils extend to the Mexican boundary and thence east through southern Arizona and New Mexico into southwestern Texas, the main body being interrupted by mountains a few miles east of El Paso. Other small isolated areas occur in intermountain basins in the trans-Pecos region of Texas. Three areas occur in western Wyoming, one west of the Big Horn Mountains, one north, and another northeast of the Uinta Mountains. All of these are shown on the soil map (pl. 5, secs. 3, 4, 5, and 6) as Jordan soils.

That part of the Great Basin region extending approximately from the northern boundary of Nevada southward or southeastward as far as the Desert soils are known to occur, consists topographically of a series of isolated, short, north-south mountain ranges separated by long alluvial fans stretching from the mountains outward, the fans from adjacent parallel ranges meeting along the axial line of the lowland belt separating the mountains. In places where the fans do not actually meet along the axial line of the lowland, they are separated along this line by a flat area which is usually subject to flooding and known as a playa. The playas constitute, however, a very unimportant part of the whole region. The mountains, as a rule, contain no soils or an extremely thin layer of soil, much thinner than is present on the various mountains of the Rocky Mountain region. The mountains are either entirely bare or are covered with a very thin cover of brush except a few ranges much higher than the average on which open forests are growing on podzolic but immature soils.

Practically all the soils of the region, except narrow belts of river alluvium, lie on the alluvial fans and playas and have developed or are developing from the materials of which the fans and playas are composed. The alluvial fans are in process of development, but deposition of material from which they develop does not take place over the whole surface of the fan at any one time. The streams which carry material from the mountains, during the occasional desert thunderstorms, onto the alluvial fans, shift from time to time and eventually distribute the material over the whole fan. In some part of every fan, therefore, the material is now accumulating or has accumulated so recently that no soil profile development has taken place. In other parts of the fans, accumulation took place a long time ago.

According to information available at present, the dominant soils in the southern part of the Great Basin region, extending from southern Nevada southward and eastward, are identified as members of the Mohave or closely related series. Enough is known to warrant the statement that in detail, many soils occur in the region, but the Mohave and closely related soils are the most important. In the central part of the region the Jordan soils are dominant, and in Idaho and Oregon members of the McCammon series occur over large areas. In the State of Washington, several series are shown on the soil map. Practically all the Desert soils, aside from color, have closely similar profiles. They differ, of course, in texture and in those characteristics which express the character of the parent material, but studies in the region have not been carried on to an extent sufficient to warrant an attempt to separate the Desert soils into minor groups. The Mohave soils, the predominant southern Desert soils, are differentiated from the others because they are reddish. The Jordan soils are brown rather than red although they have a very faint reddish tint. The McCammon soils are largely sandy, are brown or yellowish brown, having no suggestion of red, as a rule, and the same is true of the central Washington soils. The McCammon soils have been differentiated from the Jordan mainly on the basis of the character of the parent material.

The Mohave soil series has been established by detailed work in the region, and its characteristics have been clearly defined. The Jordan and McCammon series have not been definitely established, and on the soil map in this publication they represent

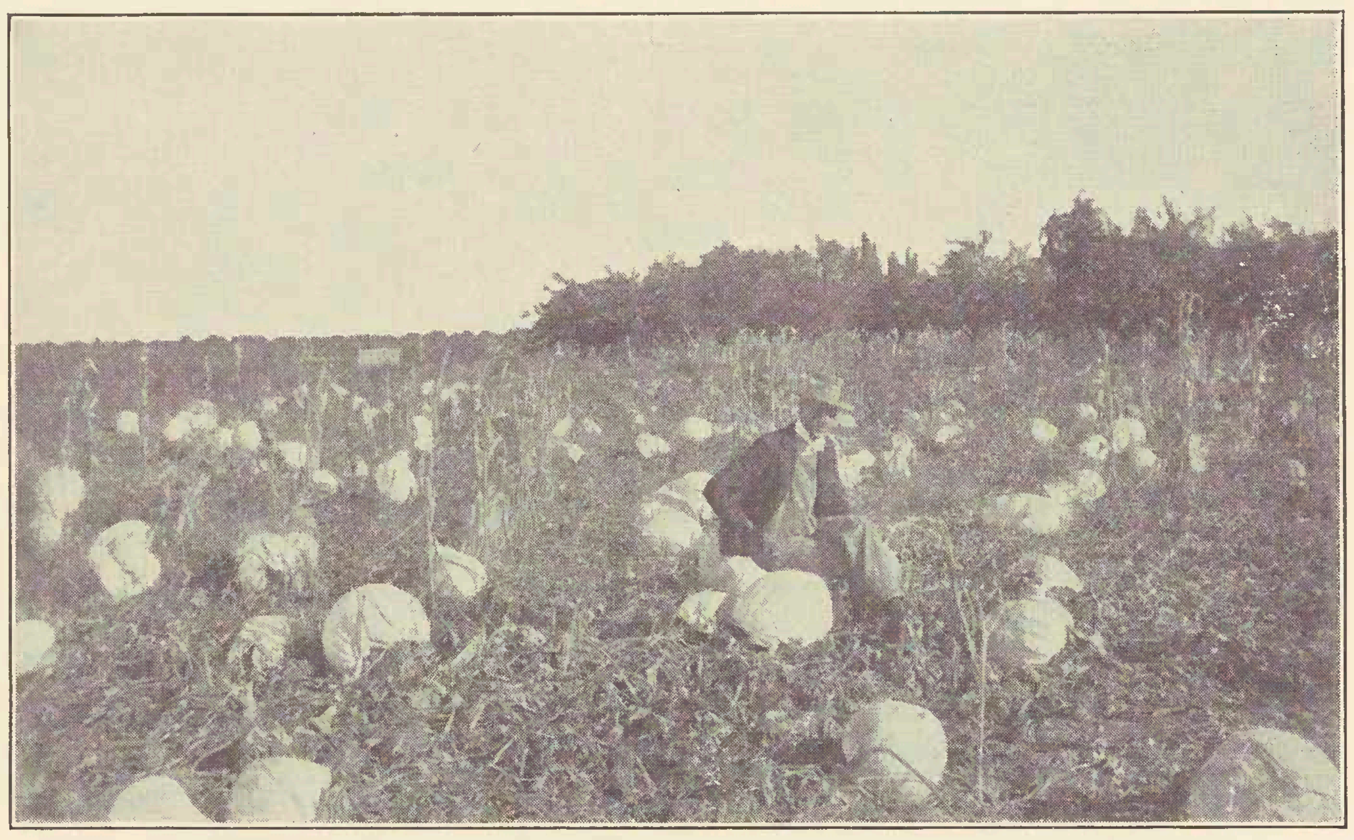


FIGURE 51.—Pumpkins grown under irrigation on a Weber (Desert) soil, near Hooper, Utah.

areas of soils, the details of whose characteristics are almost entirely unknown. It is known in a general way that they are different from those of the Mohave series but that is about all. This difference is a difference of detail, however.

Considerable areas of Lahonton soils are shown on the soil map in this ATLAS, occurring both in Nevada and in Utah. They consist of fine-grained deposits laid down in the large lakes existing in this region in Pleistocene time, and most of them are more or less salty.

Some rather large areas of Deschutes soils, another group established for this publication and map only and not yet officially defined, are shown in Oregon east of the Cascade Mountains and elsewhere. They are desert border soils, developed and developing in regions where the rainfall is sufficient to support an open cover of juniper trees. The grass cover is thin, and the soils are not so dark as the rainfall in the area where they are developing would indicate. The annual rainfall amounts to about 16 or 18 inches. The soils, because of the thinness of the grass cover, are darkish brown only.

The typical desert profile, such as that of the well-developed Mohave soils, consists of a desert pavement at the surface. This consists of a layer of gravel and small stones, lying practically bare and kept bare of fine material by the wind, which usually forms a rather firm crust capable of bearing some weight, but in most places it is not sufficiently strong to bear the weight of a man. In walking over it the crust breaks and the gravels forming it sink half an inch or more, making a well-defined track in the pavement. The gravels of the pavement are embedded in a gray, almost white, fine-grained material which is usually extremely porous or vesicular. When removed, however, the material is so delicate that it falls to pieces easily in the hand. This material lies in the lower part of the desert pavement and extends downward for an inch or two. It constitutes the material into which the pavement is pressed when trod upon. It contains within it some gravel material also. This layer is underlain by a firm structureless brown or reddish-brown layer, forming the important part of the soil, the horizon in which lie most of the plant roots. This layer ranges from 5 to 8 inches in thickness and may contain some pores and in extreme cases may be firmly cemented. It is underlain by the zone of calcium-carbonate accumulation when the soil is well developed or by alluvial-fan material if immature. Locally the zone of carbonate accumulation is indurated, especially on the old fans around the mountain bases and in the neighborhood of river bluffs. The material is usually reddish below the carbonate zone except in northern areas. The character of the alluvial-fan deposits depends on the character of the rocks in the mountains and the strength of the currents depositing them. In the Mohave soils the third horizon is

reddish brown, and the parent material also is reddish brown. In the Jordan soils it is less reddish, and in the McCammon and the soils of central Washington it is brown or may be slightly yellowish.

Locally, considerable areas of sand dunes have accumulated in the desert region, and in such cases no soil profile of any kind has developed. No soil profile has developed in those parts of the alluvial fans where the material is now in process of accumulation. Such areas in California have been mapped as members of the Hesperia series. None of these soils, however, is shown on the large map. In the east-central part of the Great Basin in western Utah is a considerable area of soils mapped as Lahonton. Small areas of the same soils are mapped in western Nevada. These are merely light-colored desert soils developed from heavy lake-laid material deposited in ancient Lakes Lahonton and Bonneville. They are usually heavy, have no desert pavement, but the profile otherwise is typically a desert profile where the material is not charged with salts. Large areas are salty.

The dominant natural vegetation in the southern part of the Great Basin is *Covillea mexicana;* in the northern part it is *Artemisia tridentata*, except on the sandy areas. On sands *Artemisia filifolia* is common. On areas of heavy soils, where the relief is rather smooth and the water supply better than on the gravelly rather steep Covillea-covered fans, mesquite of two or three species is common. During the rainy season (July and August) in the southern part of the Great Basin the ground is covered with a short growth of annuals. There is no real grass cover except in wet spots where coarse bunch grasses are common. A very sparse growth of bunch grasses occupies parts of the northern half of the Great Basin.

Irrigation is carried on in the region on the smoother less sloping fans and on river terraces, in both of which situations the soil profile is typical of the desert, or on recent alluvial belts along the few rivers. In the Imperial Valley of southern California the irrigated land consists of alluvium and alluvial fans of the Colorado River delta and old deposits in the Salton Sea.

SOILS OF THE PACIFIC COAST

The distribution of the soils of the United States east of the Sierra-Cascade system is systematic and regular, leaving again the western mountains out of consideration, each of the great groups occupying a large area practically to the exclusion of the others. Although the soils are grouped entirely according to characteristics, each great group and major subgroup occupies a well-defined area. The United States

FIGURE 52.—The results of logging operations in the forests of the Northwest on the Olympic and Aiken soils.

may be subdivided, therefore, into a number of large areas which we may designate as soil provinces, in each of which soils of a given general character are dominant.

This distribution of soils exists because of the corresponding distribution of the dynamic factors producing the soils of these great groups. When we come to the Pacific coast, however, because of the rapid changes in relief from place to place, the dynamic factors of climate and natural vegetation are not distributed uniformly over large areas. All gradations or combinations of climate and natural vegetation occur within a comparatively short distance. The Pacific coast region is mountainous, and within any mountainous region conditions differ widely within short distances. All the great soil groups which occur in the eastern part of the United States occur also in the Pacific coast region, but in no case do these great groups occur in areas large enough to make it possible to show their distribution on the soil province map. (Pl. 2.) The Pacific coast region constitutes a region of its own, one may almost say a world of its own, and it is more convenient to discuss it as a separate geographic region than to discuss its soils as members of the great soil groups. The place occupied by each of the important soils in the scheme of the great soil groups can be mentioned in the brief discussion of the soils.

Physiographically the Pacific coast region consists of two mountain ranges with a lowland belt between. Each feature extends more or less continuously from Mexico across the United States and into Canada. The Coast Range lies between the lowland belt and the Pacific coast; the Sierra-Cascade Range between the lowland belt and the Great Basin. The soils within the two mountain ranges consist to a considerable extent of freshly disintegrated material, differing widely from place to place according to the character of the underlying rock. Since soil studies have not been carried on in the mountainous region east of the lowland, nothing is known of the general character of its soils except that they are in general similar to the soils of the Rocky Mountain region and also to those of the humid region of the eastern part of the United States. Such development as has taken place, taken as a whole, is a development similar to that going on in the Pedalfers. The mountain ranges, however, where soil mapping has not differentiated the soils, are shown on the soil map as rough stony land. The soils which have so far been defined, identified, and mapped in this region lie mainly within the lowland belt, but considerable areas lie within the Coast Range and some on the western slope of the Sierras.

The northern end of the Pacific coast lowland consists of the low hilly region around Puget Sound. In the soil mapping, done several years ago in this end of the lowland, a number of soil series were differentiated. All of these soils, however, belong to the Pedalfer group. They are brown soils, slightly podzolic, and they constitute faintly podzolized members of the Gray-Brown Podzolic group.

In the vicinity of Puget Sound the soil material has been accumulated by glacial processes. The Pedalferic soils developed from this material are shown on the map as members of the Everett series. They have developed under a dense forest cover, and although a great deal of organic matter is dropped to the soil from the trees, none of these soils has developed the Podzol profile except locally in the highest parts of the mountains. The organic-matter layer is thin, except where masses of decaying tree trunks and woody materials have accumulated, although much of it is made up of material from conifers, mainly fir. In few places is this layer more than 2 or 3 inches thick, and it is not underlain by a bleicherde, or gray layer. The A horizon of the mineral soil is brown, not so light in color as is the corresponding horizon in the Gray-Brown Podzolic soils. The B horizon is a little heavier and somewhat lighter brown than the A horizon, eluviation not being noticeably developed. This layer, in turn, is underlain by the parent glacial material derived from crystalline, metamorphic, and volcanic rocks, mainly the latter.

Small areas of Springdale soils are associated on the map with the Everett soils. They differ from the latter mainly in the presence of a somewhat sandy subsoil. Most of the areas are small, and although differentiated in detailed mapping, are here included with the Everett soils. Spanaway soils occupy several square miles in the southern part of the Puget Sound region. They are rather conspicuous in the region because they constitute most of the very smooth land. In most cases the density of the forest growth is considerably less on these soils than on Everett soils, and as a result the grass growth is better and the soils have a somewhat darker color than soils of the Everett series.

The Everett soils, being confined to the glacial region, do not extend south of the country immediately surrounding Puget Sound. The Springdale soils occur within the same general limits in western Washington but in eastern Washington and in the panhandle of Idaho they occupy important areas, everywhere in association with the Everett soils.

The important alluvial soils of the Puget Sound Basin have been grouped for the purpose of this ATLAS into one series, the Toutle. They range rather widely in the details of their features but consist, for the most part, of material brought from existing glaciers or from mountain-side young glacial material containing a high percentage of gray volcanic ash, some pumice, and other volcanic material.

Small strips of Chehalis soils occur along streams mainly south and west of the main Everett area. They are well-drained brown alluvial soils, the material being derived mainly from mixed sedimentary and igneous rocks.

The Coast Range in Oregon, Washington, and northern California contains considerable areas underlain by soft brown sandstone. This sandstone, with its associated shales, occurs also in the interior lowland belt, especially in the Willamette Valley in Oregon. In the latter region the soils developed from material accumulated by the decay of this sandstone are similar in general characteristics to the Everett soils, but differ from the Everett in their darker color. This is not entirely true of the soils of this series occurring immediately along the Pacific coast where they developed under dense forest cover. In the Willamette Valley, however, the Melbourne soils, as these soils are designated on the soil map (pl. 5, sec. 4), have a distinct dark color, owing to their development under an open forest in which a grass cover was present. They are characterized by rather dark brown surface soils, very slightly podzolized, with yellowish-brown somewhat heavier subsoils.

The dark color of the Melbourne soils is not confined to these soils alone but is characteristic of practically all the soils of the Willamette Valley part of the Pacific lowland. The important soils in the latter region, in addition to the Melbourne, include soils of the Willamette, Amity, and Aiken series, together with a narrow strip of Sacramento soils, differentiated into several series in detailed mapping, along Willamette River. The Willamette soils constitute the mature soils of the region, developed from material washed into the lowland belt from the adjacent mountains, and they consist to a considerable extent of material from basaltic rock. Like the Melbourne soils they were developed under a thin forest cover with considerable grass cover. They have a well-defined dark shade in their surface soil, but in other respects the profile is essentially identical with that of the Everett soils, with the exception that in some places the material beneath these soils is lighter in texture than that in the solum. The texture of the material differs within comparatively narrow limits. Enough eluviation has taken place to have developed a B horizon slightly heavier than the A horizon.

The Amity soils are imperfectly developed, lying on flat surfaces on the floor of the Willamette Valley. They have developed under imperfect drainage. In some places, where drainage has been less perfect than normal, a heavy clay horizon has developed at a depth ranging from 15 inches to 2 feet. In other places the claypan has not developed, but the surface soil is light in color though not white.

The Aiken soils are an important soil series, and they extend from Columbia River well into California. In the Columbia River region they lie within Willamette Valley and also on the lower slopes of the adjacent mountains. (Fig. 52.) In California they occur only on the mountain slopes in situations where the rainfall is high enough to cause the development of the Pedalfer profile. They are Pedalfers in process of development from material accumulated by the decay of basaltic rocks. Like all the soils within the Willamette Valley they are darker colored in the surface soil than the normal forested soil of the Pedalfer group. This is because of the fact that although they have developed under a high rainfall, the rainfall, because of its distribution, was not everywhere sufficient to maintain a dense forest growth, and a grass cover developed among the trees of the open forest. The B horizon, such as has developed, is reddish in color, and in California, because of higher temperatures, it is redder than in Oregon. In both localities the soil is a humid soil or Pedalfer.

The Aiken soils as shown on the map include a considerable number of soils differentiated on the detailed soil maps of western Oregon and Washington where most of them have been mapped. (Fig. 53.) The dominant soils in this region have developed from material accumulated by the decay of basalts or from basaltic material carried into the valley by streams and allowed to decay on the valley floor. In both cases the soils, being young, are influenced by the strong character of the parent rock, this manifesting itself especially in the color of the soil, because of the high percentage of iron-bearing minerals in the rock. The Aiken soils occupy the higher parts of the eastern slopes of the Cascade Mountains in Oregon and Washington, lying above the belt of Deschutes soils.

Although the soils of the Oregon part of the Pacific lowland are dark, all of them lying within the basin of Willamette River seem to be well-defined members of the Pedalfer group. South of the head of Willamette River, where the lowland is hilly, are many small areas in isolated valleys where, because of the surrounding topography, the rainfall is low. The soils have a well-defined dark color and a profile characteristic of members of the Pedocal group. It is rare to find anywhere in this region soils with a well-defined Chernozem profile. Such soils are present, however, especially in the Rogue River Valley in southern Oregon, in a considerable area although one not large enough to show on the map. These soils have developed from basaltic material, as have most of the soils of the valleys of northern California, north of Mount Shasta, and of southern Oregon. On the soil map in this ATLAS (pl. 5, secs. 4, 5, and 6) they are shown as members of the Deschutes series.

In the Rogue River Valley these soils are associated with light-colored soils having very striking characteristics, the development of which has not yet been worked out. The lighter colored soils have developed from relatively old (geologically) alluvial deposits in the Pacific lowland. Although they have been subjected to the influences which have developed the Pedocals associated with them, they are wholly lacking in pedocalic characteristics. The latter have developed on the young and relatively young deposits of these lowlands, whereas the former have developed on the older deposits. Soils of this general character, the striking feature of which is an indurated horizon, in some cases taking the form of sandstone or conglomerate at a depth ranging from a foot to several feet, have been mapped as members of the San Joaquin series.

The San Joaquin soils are typical California soils, but the soils with indurated layers in southern Oregon are included with the San Joaquin on the map in this publication, though in detailed mapping they are differentiated into other series, depending on the details of profile characteristics and on the parent material from which they have developed. In a few places in the basins of southern Oregon, where the rainfall at the present time is rather low, soils developed from granitic material accumulated by the processes of residual decay have somewhat the same profile. Such a profile is undoubtedly, therefore, the product of development and not a product of the parent material.

A small area of Sierra soils is shown on the soil map (pl. 5, sec. 4) in southwestern Oregon. They are red or reddish slightly eluviated soils developed from material accumulated by residual decay of granitic rocks. Their profile is better developed than that of the Aiken soils, but the material is lighter in texture. This area includes some brownish soils from granitic material. The Sierra soils are typically developed

FIGURE 53.—Logged-over land on the Olympic and related soils, Chehalis County, Wash.

on the west slope of the Sierras in California. In the Oregon area they are less red than in their type region.

The San Joaquin soils in California are developed mainly in a belt along the eastern side of the San Joaquin-Sacramento Valley, from Anderson southward to the south end of the valley. (Fig. 54.) The materials have been deposited in the valley by streams flowing from all parts of the Sierra Range, differing widely in lithologic character from place to place.

In a few places soils of similar character have been given other names, but soils of the same general character form a broken, somewhat discontinuous belt from one end of the California lowland to the other. A string of isolated areas extends down the west side of the valley from the northern end to the bay region. In detailed mapping they are designated as Corning, Redding, and Tehama soils. They are all soils with indurated or very heavy layers in some part of the profile. In many cases the San Joaquin soils consist of a light-colored, usually brown or reddish-brown, surface horizon ranging in texture from sandy loam to clay and underlain by heavy columnar clay. The transition from the A horizon to the heavy clay is abrupt, the heavy clay lying, at least in places, though whether this is universal or not is not yet known, immediately above the indurated horizon. The heavy clay layer has the morphological characteristics of a Solonetz horizon, but studies have not yet been made on the material to determine whether it is such or not.

The San Joaquin soils represent the extreme development of their particular characteristics. The Madera soils, associated with the San Joaquin soils in California and included with them on the soil map in this ATLAS, have similar features but are in a much less advanced stage of development. They are brown, lie on smoother relief, and occupy such situations as to indicate geologically and physiographically their development from younger material than that from which the San Joaquin soils have developed. The indurated layer is poorly developed and may contain some calcium carbonate, whereas the indurated layer of the San Joaquin soils contains carbonates in very few places. In fact calcium carbonate may be considered entirely absent.

Another group of soils associated with the San Joaquin and the Madera, in which an indurated horizon is only incipiently developed, in this case the induration being due to cementation by calcium carbonate, consists of the soils mapped as Fresno. The Fresno soils are younger than the Madera and San Joaquin. It is not yet certain whether they are developing in a line parallel to the development of the San Joaquin. It is not at all certain that the San Joaquin, and possibly also the Madera, are not the product of development under a former and different climatic environment from that now prevailing in the region. If this be the case the Fresno soils presumably are not undergoing development parallel to that of the San Joaquin. Much of the area of the Fresno soils has been impregnated, during the last half century, with alkali from seep water from higher lying irrigated areas, so that, as a whole, their real characteristics are obscure in the area of their occurrence. About all that can be said of them here is that they are light-colored soils without a heavy clay horizon and that they contain a zone of faint carbonate cementation and presumably of carbonate accumulation. The San Joaquin, Madera, and Fresno soils lie along the eastern side of the Sacramento-San Joaquin Valley and along the west side from the north end southward to Willows.

One other important group of soils, occurring in two important areas, is on the east side of the valley. This is Stockton, represented by the clay adobe. This is a black soil in which the dark color extends to a depth of 2 feet or more and beneath which the soil material is impregnated with calcium carbonate. It is not yet known whether the carbonate constitutes a zone of accumulation, and therefore whether the Stockton soils can be correlated as members of the Pedocal group. One of the environmental factors which tends to make such correlation doubtful is their occurrence in low situations. The northern area lies a few miles south of Chico and between alluvial fans built by the American Fork of the Sacramento River to the south and Chico Creek and other streams to the north. The soils are subjected to excessive wetness during the rainy season but in summer become extremely dry, and because of their heavy texture wide cracks are formed in the surface soil. It is not known whether the characteristics of these soils are due mainly to their water logging through a considerable part of the year or to their development in a climatic environment which is undoubtedly very close to that under which Chernozems are developed. The annual rainfall is about 20 inches or a little more. It falls during the winter season, whereas the long summers are practically rainless. Soils developed under good drainage conditions and now characterized by a well-defined Chernozem profile are found in the region only a very few miles from at least the southern area of Stockton soils where climatic conditions are practically identical with those in the Stockton area.

In addition to the soils already described, including those of the San Joaquin, Madera, Fresno, and Stockton series, a broad belt of alluvial soils lies along the axis of the San Joaquin-Sacramento Valley and considerable areas lie in fanlike forms here and there along the eastern side. Each of the latter areas is spread out fanlike from the point along the boundary of the valley where the large stream depositing it enters the valley from the mountains. These bodies always occur in fanlike form, the stem of the fan consisting of the river itself just above the point where it enters the valley. The fans range up to 20 or 30 miles in diameter both east and west and north and

FIGURE 54.—Bare spots on San Joaquin soils, near Oroville, Calif.

south. These soils, which are members of the Hanford series, have no soil profile since they consist of freshly laid alluvium made up of material brought into the valley from the Sierras. The material is brown, noncalcareous, and usually sandy loam. These soils occur not only along the east side of San Joaquin Valley but also in the Los Angeles region and in other valleys in California, especially southern California. They constitute the highly productive soils of the region. (Fig. 55.) Along the axis of the valley, in situations subject to seep water and a great deal of flooding, the soils are sometimes impregnated with salts.

The soils along the west side of the valley from the vicinity of Los Banos southward have developed under extremely low rainfall. This is also true of the soils on the east side of the southern end of the valley, but the large rivers entering from the Sierras have determined the character of the large areas of alluvial soils consisting of members of the Hanford series. The older soils on the east side of the valley, as already mentioned, seem to have developed under different conditions from those now obtaining. The soils on the west side of the valley, however, are the product of the existing environment. They are Desert soils, having developed under a rainfall ranging from about 16 or 18 inches at Los Banos to about 8 inches south of that place. They have the typical Desert profile similar to that of the soils in the Great Basin, as already described, especially in the southern part of the basin, and they are mapped as members of the Panoche series. North of Los Banos the rainfall is higher, sufficient to cause the development of dark-colored soils. The soils which have developed a regional profile on the smooth relief in the region extending from the vicinity or a short distance north of Los Banos northward to the latitude of Sacramento, are soils with a characteristic Chernozem profile. They are black, have well-developed structure and a well-defined zone of carbonate accumulation. This applies not only to the soils developed from material lying on the floor of the valley and accumulated by sedimentation, but also to materials lying on the lower slopes of the hills west of the valley and formed from material accumulated by the decay of sandstones, shales, and other rocks.

The soils on the west side of Sacramento Valley, south of Willows, consist mainly of young alluvium derived from the eastern part of the Coast Range, where the rainfall is relatively high and where the material is moderately well leached. Being young, they have not lain in place long enough to develop a profile characteristic the region in which the material has been laid down. Practically all the development that has taken place is the accumulation of some organic matter. They are brown soils without soil profile and are mapped as members of the Yolo and associated series.

A relatively important associated series is the Capay. These soils may be designated as slightly salty Yolo soils. Other soils along the western side of the valley, not including the Sacramento soils along Sacramento River, are older than freshly deposited alluvial soils, having developed from relatively old colluvial deposits. They have already been described as soils with a profile in general similar to that of the San Joaquin soils.

Along the west side of the Sacramento Valley, mainly north of Woodland and south of Corning, is a comparatively important belt of Willows soils. They are brown, developed from young alluvial deposits by small streams flowing from the eastern, mainly sandstone, ranges of the Coast Range. They have a faintly developed profile, slightly better developed than that of the Yolo soils.

Many isolated lowland areas lie inclosed within the ranges of the Coast Range. In many of these the soils have been mapped, and a great number of series have been differentiated. In general these soils may be grouped into two general classes—those consisting of fresh alluvium similar to the Yolo soils on the one hand, and soils developed from older material and therefore much older soils in which the profile is developing more or less definitely in the direction of the San Joaquin.

In the vicinity of San Francisco and southward the number of soils differentiated in detailed mapping is very large. This is done partly on the basis of the character of the parent material and partly on that of profile development. The region is mountainous; the rocks are folded and consist mainly of sedimentary beds in which important changes in character may take place within very short distances. Most of the light-colored soils are very young, consisting of little more than accumulated parent material, and are mapped as members of the Altamont series. They extend throughout the humid part of the Coast Range.

In only one locality south of San Francisco is the relief within the Coast Range smooth enough over an important area to allow the development of a series of soil belts corresponding to different climatic environments. This area consists of a dissected plateau lying around the head of Salinas River, extending mainly eastward from the city of Paso Robles which lies within the plateau and on Salinas River. The western boundary lies approximately 20 miles east of the coast and is separated from the coast by a range high enough to intercept much of the rainfall that would otherwise reach the region. The west side of this range is highly humid. Immediately east of it, in the vicinity of Paso Robles, the rainfall amounts to about 20 inches. Eastward it decreases, except where it is comparatively high because of

FIGURE 55.—Irrigated orange grove on Hanford soils in Orange County, Calif.

higher elevation on ridges, more or less uniformly to the southern end of the San Joaquin Valley, where, as already stated, it amounts to about 8 inches only.

A series of moderately well defined north-south belts of soils succeed each other from west to east, that containing the darkest soils lying along the west side of this series of belts; that containing the lightest colored soils lying along the west side of the San Joaquin Valley. Their recognition is rendered somewhat difficult because of the dissection, because of the occurrence of areas and narrow belts of highly calcareous parent material on which Rendzinas have developed, and because of a number of high ridges on which the rainfall is higher than on the lowland. The soils lying along the coast are Podzolic where maturely developed.

In the vicinity of Paso Robles and eastward for several miles the soils are dark, not black but darker than those farther east. Eastward there is a progressive change to a lighter color until the light-colored Panoche soils are reached in the Antelope Plains some 40 or 50 miles east of Paso Robles. In smooth situations in the vicinity of Paso Robles the soil profile is characterized by a dark-colored surface soil, and at a depth of about 3 feet lime carbonate is present. These soils lie only on remnants of the plateau and in situations where the soils have developed from the underlying shales and not from a bed of sandy material which seems to have been deposited on this plateau after it was developed as a plateau and before the dissection by which it is now characterized. Where this sandy material has been removed from these ancient plateau remnants the soil developed from the local material has the characteristics described. The soils developed from the old sandy material are relatively light in color and may consist of an ill-defined profile which could possibly be regarded as a sandy Chernozem, but because of their necessary occurrence on flat areas they have developed the indurated or heavy clay horizons which in southern California are almost invariably present in soils developed on such areas of relatively old deposits. These consist of claypans or hardpans.

East of the belt of dark-colored soils is a belt of Dark-Brown soils, and this belt, in turn, is succeeded by Brown soils, and finally by the Desert soils of the Panoche series. Since the rocks, from which the parent material of these soils has been accumulated by decay in place, are often calcareous, there are considerable areas of Rendzinas lying not only in the Paso Robles belt of dark-colored soils but also in the Dark-Brown and Brown belts east of Paso Robles. These Rendzinas are everywhere dark and because of their presence tend to obscure the normal climatic soil belts of the region. These soils are shown on the map as members of the Dublin series, and the Dark-Brown soils in the belt east of the Paso Robles area of dark-colored soils are shown on the map as members of the Encina series.

The Salinas Valley, north of Paso Robles, assumes, within a short distance, the features of a moderately broad intermountain valley occupied by a moderate-sized river throughout its length. It is essentially an intermountain lowland belt occupied and modified by a river. The valley proper of the river ranges up to somewhat more than 2 miles wide and is flanked by the upland of the lowland floor, consisting of smooth, gentle slopes of colluvial material spread out on the floor by small intermittent mountain streams. A number of lowland belts similar in origin to the Salinas Valley lie inclosed within the mountains. The floors of these valleys also are covered by colluvial deposits.

Along the coast and for a few miles inland the rainfall is sufficient to have produced slightly Podzolic soils, but from the city of Salinas southward the floor of the valley has a rainfall ranging from about 10 inches on the lowland floor to 20 inches at elevations of about 2,000 feet above sea level and a still greater rainfall occurs on the higher areas.

The soils on the main valley floor, and those of the lower lying subordinate lowland belts above Salinas, approach the soils of the San Joaquin series in general profile features where developed on the older deposits. Those on the younger deposits, both in the river valleys proper and on the recently formed alluvial fans consist of loose, usually sandy material with no soil profile features other than slight accumulations of organic matter, whereas deposits of intermediate age are covered with soils in intermediate stages of development. The striking feature of the soils on the smooth lowlands of the whole region is the presence, in practically all of them except the youngest, of a solonetzlike profile in various stages of development. (Fig. 56.) On the soil map in this ATLAS all these soils on the alluvial fans have been placed in the Placentia series, but in detailed mapping they have been differentiated into a considerable number of series of which only small areas have been identified as typical Placentia soils.

The soils on the mountain slopes as a whole are dark, shallow, and contain large and small rock fragments usually in abundance. A large number of areas on the west slope of the range east of the Salinas Valley have been identified as Rendzina soils but it has not yet been finally determined that they are not approximately mature members of some series belonging in the Pedocals. Their association with soils identified as Kettleman, a series of soils developed only under very low rainfall, presents a problem for future solution.

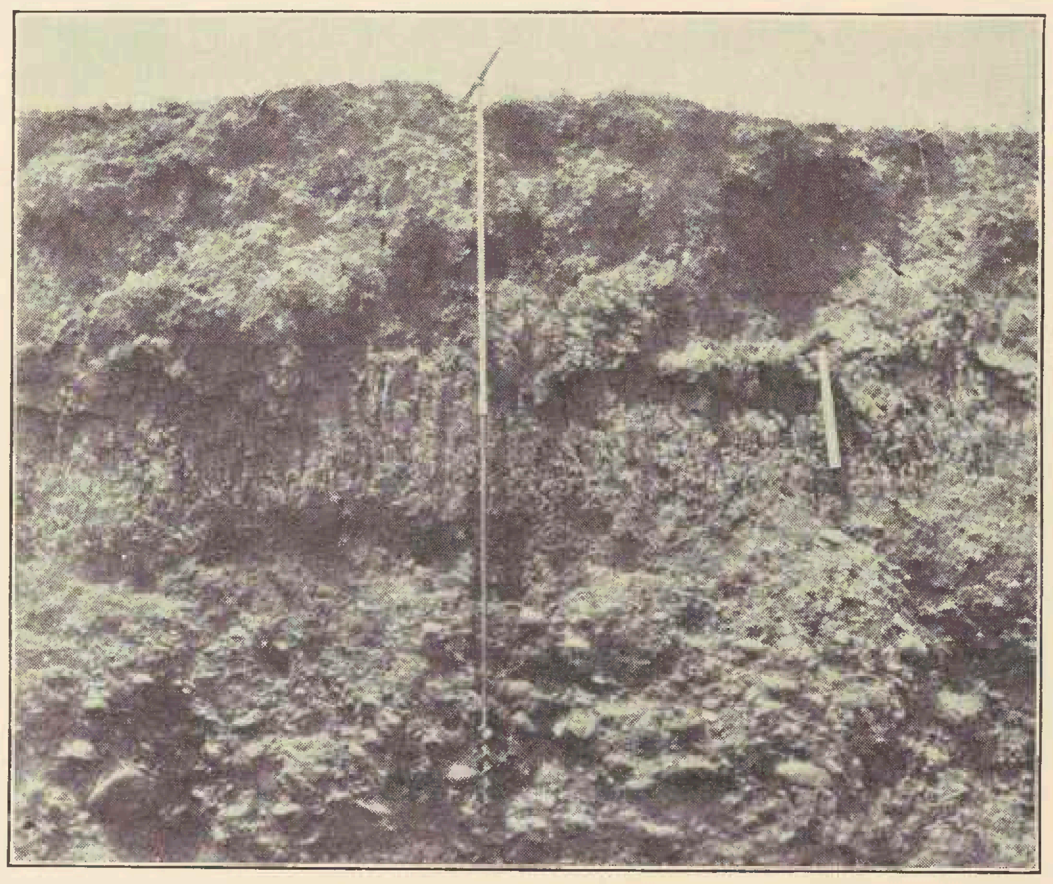


FIGURE 56.—Profile of a soil with a Solonetzlike horizon, near King City, Calif.

Soils with heavy clay layers having all the morphological characteristics of Solonetz soils are of common occurrence along the coast of southern California. Their chemical characteristics have not yet been studied, so it is not definitely known whether or not they are true Solonetz soils.

South of Santa Barbara the lowland areas west of the desert in southern California are practically all open to the sea. They consist of the Ventura and San Fernando Valleys, the large basin which may be designated as the Los Angeles lowland, the Imperial Valley, and the lowland along the coast south of Santa Ana. Small isolated areas of smooth relief, constituting imperfectly developed lowlands, lie in the low mountain region between the Pacific coast and the northward extension of the Imperial Valley, but as they are all small the details of their soils can not be shown on the soil map. In those lowland belts, where the material underlying the lowland floors and constituting the soil materials have been derived from the sedimentary rock of the coastal ranges, the alluvial soils, which have not yet developed a profile, are mapped as members of the Yolo series. Those lying in more elevated situations and constituting material washed into the valley at an earlier date and on which a soil profile has developed are shown on the map as members of the Placentia series. Numerous series have been identified and mapped in the detailed mapping of this region, but the area of occurrence of each one is so small that it is impossible to show its distribution on the map. The soil map in this ATLAS represents a generalization of the soils in these small areas and expresses only the most general soil differences within them. Because of the small areas of these valleys, even this expression can not be well brought out because of the detail required.

The dominant soils in the Los Angeles lowland and the San Fernando Valley are members, as shown on the map, of two general groups of series. One is shown as Hanford soils, the other as Placentia. The difference between these two is a matter of stage in development. The Hanford soils, as already explained in describing them as they occur in the San Joaquin Valley, are recent-alluvial soils and differ from the Yolo soils in having been developed from material derived from granitic rather than sedimentary rocks. The Hanford soils are brownish soils without soil profile, or essentially so, and are not calcareous. In some places in the Los Angeles region where the deep part of the subsoil has been subjected to ground water influence, effervescence takes place. This, however is not, as a rule, due to the calcareous character of the parent material of which the Hanford soils are composed but to impregnation by ground water.

The Placentia soils have a well-developed profile, though apparently not entirely normal, derived or developed from material carried into the valley a long time ago.

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF CHEMISTRY AND SOILS
HENRY G. KNIGHT, CHIEF
A. G. McCALL, CHIEF, SOIL INVESTIGATIONS
CURTIS F. MARBUT, IN CHARGE SOIL SURVEY

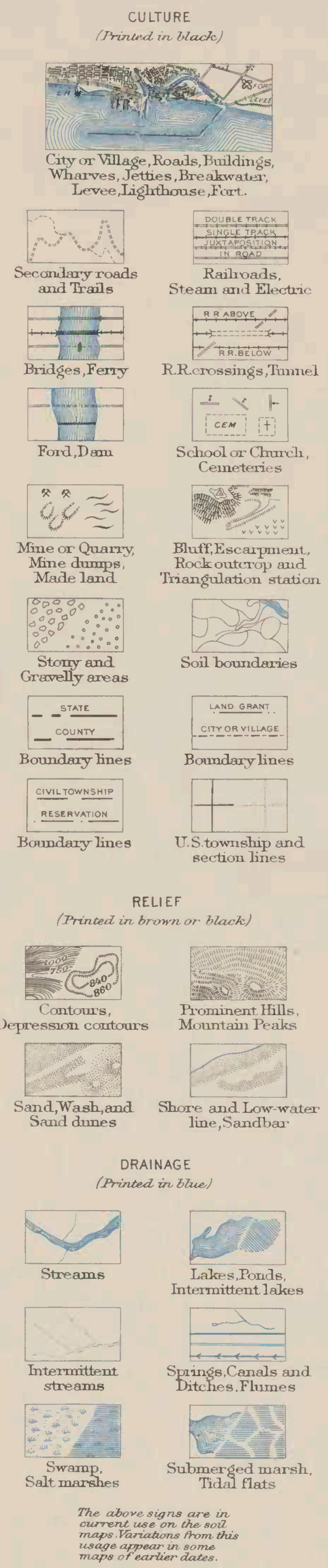
SOIL MAP

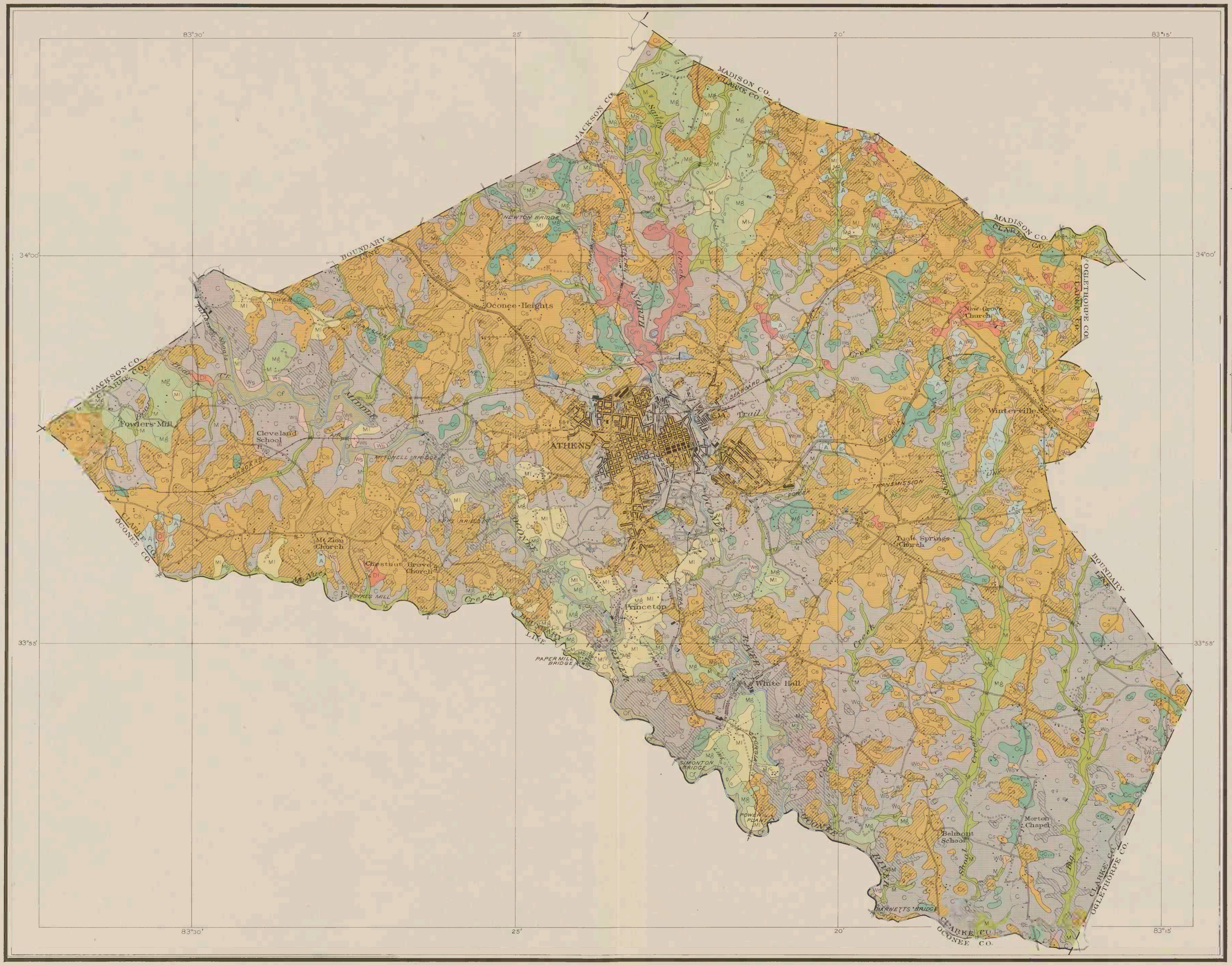
CLARKE COUNTY

GEORGIA

GEORGIA STATE COLLEGE OF AGRICULTURE
ANDREW M. SOULE, PRESIDENT
L. M. CARTER, HEAD, DIVISION OF AGRICULTURAL CHEMISTRY

CONVENTIONAL SIGNS





LEGEND

A	Appling sandy loam
Cf	Congaree fine sandy loam
Cs	Cecil sandy loam
Cs	Cecil sandy loam, Mixed phase
Cm	Congaree silty clay loam
Dl	Durham sandy loam
Cc	Cecil sandy clay loam
Mg	Madison gravelly sandy loam, Mixed phase
C	Cecil clay loam
C	Cecil clay loam, Steep phase
Ml	Madison sandy loam, Mixed phase
Ws	Wickham sandy loam
M	Meadow
Wo	Worsham sandy loam

W. Edward Hearn, Inspector, District 2
Soils surveyed by G. L. Fuller, Georgia State College of Agriculture

1 ½ 0 1 2 3 4 Miles

Scale 1 inch = 1 mile

A. Hoen & Co., Inc. Lith.

Field Operations
Bureau of Chemistry and Soils
1927

They are noncalcareous, and the profile seems to be developing somewhat parallel to the development of the San Joaquin soils. The surface soil is brown. The subsoil ranges from yellowish brown to strong brown, is heavier than the surface soil, is somewhat compact, and in some places is indurated. It is apparent also that in situations near the coast the subsoil assumes the characteristics of a Solonetz horizon. Recent studies, as already stated, have shown the rather widespread distribution along the coast of such a horizon. Farther inland, however, instead of a Solonetz horizon, there is a tendency to induration. The important agricultural soils of the Los Angeles region are mainly members of the Hanford series, but the better members of the group shown on the map as Placentia are also under a high state of cultivation and are productive soils.

Along the coast south of Los Angeles and between the coast and the mountains lying farther inland is a dissected plateau which seems to consist of an elevated sea bottom, in which considerable areas of undissected plateau surface still persist. On such areas the soils have developed, as a rule, profiles of extreme characteristics either containing solonetzlike or indurated horizons. It is not yet known what proportion of the total area is made up of such old soils, some of which belong in the San Joaquin group. The younger soils belonging to various series, depending on the character of the particular bed of material from which they have been developed and the stage of development attained, have been shown on the soil map in the ATLAS mainly as Placentia, but in detailed mapping they have been differentiated into a large number of series.

East of Oceanside the mountains bounding the coastal plateau consist of granite. In a rather small area around the towns of Escondido and Fallbrook the granite has weathered into a soil with a well-defined profile. The surface soil is dark brown, and the B horizon is well-defined bright-red clay or sandy clay. The B horizon is underlain by disintegrated granite.

These soils are similar in general character to the soils occurring in many places along the western slope of the Sierra Nevadas from southern California northward. Most of them have been mapped as members of the Sierra series. It is now well known that they are not identical with, although highly similar to, the Sierra soils. They differ from the latter in that in some localities they have developed under a relatively high rainfall and a forest cover and in others under a rainfall about sufficient to favor the development of a Chernozem profile. This seems to be the case of the soils in the vicinity of Escondido, which have ill-defined Chernozem profile characteristics.

The Imperial Valley and its northward extension, up to what is known as the Banning Pass, is part of the desert of southeastern California. The soils, however, are not all Desert soils, as the most important of them consist of freshly deposited material brought into the region by Colorado River and deposited in a northern extension of the Gulf of California. In recent geological times this area has been separated from the main part of the gulf by the fan across it built up by Colorado River which enters its eastern side rather than its upper end. The Imperial Valley soils consist of this freshly deposited material and are shown on the map as members of the Imperial series. Many series have been identified and mapped in detailed mapping, but their general characteristics are similar. Beyond the area of recent sedimentation the soils are Desert soils and have developed, in general, the characteristics of the Mohave series.

COMPOSITION OF THE PEDOCALS

COMPOSITION OF THE CHERNOZEMS

The Pedocal belts extend across the international boundary from the United States into Canada, each of the belts running northwestward across that country to the foot of the Rocky Mountains. In making a rapid examination of the soils in the prairie provinces, several years ago, a sample of a Canadian Chernozem was collected from the vicinity of Krydor, about 70 miles northeast of North Battleford. The sample was analyzed in the laboratories of the Bureau of Chemistry and Soils, the results being shown in Table 151.

TABLE 151.—*Composition of a Canadian Chernozem, Krydor, Canada* [1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
33020	1	0-5	a 64.73	0.39	3.22	9.76	0.147	1.70	1.00	2.03	1.45	0.17	0.20	15.55	100.35	0.557	------
			b 76.65	.46	3.81	11.56	.174	2.01	1.18	2.40	1.71	.20	.23	------	100.53	------	------
33021	2	8-14	a 71.02	.49	3.49	11.27	.035	2.27	1.38	2.22	1.61	.13	.07	6.12	100.16	.152	1.01
			b 75.65	.52	3.72	12.04	.030	2.41	1.47	2.36	1.71	.13	.07	------	100.17	------	------
33022	3	14-24	a 59.26	.40	3.28	9.95	.033	8.40	3.13	1.85	1.34	.14	.07	12.11	99.99	.129	7.78
			b 67.42	.45	3.73	11.32	.071	9.55	3.56	2.10	1.52	.16	.08	------	99.96	------	------
33023	4	24-65	a 66.11	.63	6.18	14.17	.048	1.97	2.19	1.85	1.27	.08	.12	4.85	99.47	.033	.85
			b 69.48	.66	6.49	14.89	.050	2.07	2.30	1.94	1.33	.08	.12	------	99.41	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
33020	1	0-5	0.3	3.2	2.5	12.2	10.1	58.4	12.9	99.6
33021	2	8-14	.8	3.4	2.8	8.3	17.6	56.1	11.4	100.4
33022	3	14-24	.4	1.6	.6	7.3	15.8	56.5	17.0	99.2
33023	4	24-65	.2	.3	.6	29.7	16.4	28.6	25.0	100.8

[1] Collected by C. F. Marbut. [2] Analyzed by G. Edgington. [3] Analyzed by V. Jacquot.

As in all the analyses, the results of which are presented in this publication, the composition of each horizon calculated to a mineral basis is shown. This shows at a glance the concentration of calcium oxide and carbonic oxide in horizon 3. Horizon 1 contains no carbonates; 2, a small quantity; 3, about 16 per cent; and 4, the parent glacial till, practically unmodified except by a possible small accumulation of sulphates, less than 3 per cent. Horizon 3 is clearly a horizon of carbonate accumulation. The accumulation of carbonates, in which both calcium carbonate and magnesium carbonate presumably are present, masks the relative percentages of other constituents and especially the presence of any of these constituents in any horizon into which it may have been shifted by soil-developing processes. The presence of magnesium carbonate in the accumulated carbonates in horizon 3 is shown by the higher percentage of magnesium oxide in that horizon than in the parent drift.

Presumably all the accumulated CaO and MgO in the soil is present as carbonate. The 9.55 per cent of CaO includes therefore the original CaO and the shifted CaO, part of the former being carbonate and part in some other combination presumably silicate. There seems to be no means of determining exactly the percentage of CaO in both forms present before concentration began. The only possible assumption, apparently, is that the amount in horizon 3 was the same as that in horizon 4, or 2.06 per cent. On the same basis the percentage of MgO in 3 was 2.30. On the basis of this assumption the percentage of accumulated MgO is 1.20 and of CaO, 7.49 or a total of 8.69 per cent of accumulated alkaline earth expressed as oxide. A slight correction is necessary in horizon 2 also.

When the table of analyses for all the horizons has been recalculated after eliminating the accumulated material as described above, the resulting composition is as shown in the last three columns of Table 152.

TABLE 152.—*Sample of a Pedocal, Krydor, Canada*

Sample No.	Depth in inches	Ratios			Molecular equivalent composition			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO (2.06) and MgO (1.20)		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
33020	0-5	11.27	53.31	--------	1.271	0.0238	0.1131	83.30	4.14	12.56	76.65	3.81	11.55
33021	8-14	10.71	54.04	--------	1.254	.0232	.1174	82.75	4.07	13.17	75.88	3.72	12.07
33022	14-24	10.12	47.74	--------	1.105	.0232	.1095	81.75	4.52	13.72	73.97	4.08	12.39
33023	24-65	7.95	17.69	--------	1.152	.0405	.1453	75.60	7.03	17.34	69.48	6.49	14.89

The low percentage of silica and the high percentage of sesquioxides in layer 4 (24–65 inches) is striking in amount and in position. If they occurred in layer 2, we should merely interpret the result as a product of podzolization. Occurring in the layer below the carbonate accumulation zone, it is evident that podzolization can have had nothing to do with it. The percentage of alumina in layer 1 is slightly lower than in 2 or 3, but the failure of the iron oxide percentages to run in a similar way but actually in the opposite direction constitutes strong evidence that the former is not due to podzolization. If the composition of layer 1 were recalculated to a CaO percentage of 2.06, this difference between alumina in 1 and 2 or 3 would be increased, but the iron oxide percentage would be increased also.

The sa and sf ratios and the molecular equivalent composition, shown in Table 152, bring out the same relationships of the sesquioxides and silica as are shown in Table 151, but even more strikingly than in the latter table. This table, as well as that showing ratios and molecular equivalents, shows a higher percentage of sesquioxides in the layer below the zone of carbonate accumulation. The sf ratios are especially striking in this respect. The ratios in layers 1, 2, and 3, the latter being the carbonate accumulation layer, are rather uniform, though the accumulation of iron oxide, or decrease in silica, seems to have begun in the carbonate accumulation layer. In 1 and 2 the sf ratios are essentially identical. If incipient podzolization were present it should manifest itself in a difference of ratio between these two. Such difference as is present points to a slightly higher content of iron oxide in the 5-inch surface horizon than in the layer below. The reverse would be the case if podzolization had taken place.

The relation of the sa and sf ratios in layer 4, compared with those in the higher layers, shows that the sesquioxide accumulation in 4 concerns iron oxide mainly, the alumina being affected to a much less extent. The sf ratio in 4 indicates about three times as high a percentage of iron oxide in 4 as in 2 or 1 and very nearly that amount in 3. The concentration of iron oxide in 4 is shown also by the molecular equivalent composition where the iron oxide in 4 is about twice that in the other layers, while the alumina in 4 is only about 30 per cent higher than in the other horizons. The sa ratios indicate about the same difference.

If the higher sa and sf ratios were the result of a serious loss of silica from layer 4 the percentages of increase of iron oxide and alumina would be the same. Since these are widely different it is evident that it must be accounted for as an actual higher percentage of sesquioxides, of which the iron oxide increase is greatest.

The shifting of sesquioxides or constituents other than the alkalies and alkaline earths can be clearly expressed by eliminating the accumulations of the latter group of constituents or by neglecting all the constituents determined, except the sesquioxides, and calculating these to 100. The results of this calculation are shown in Table 152.

The relative magnitudes in the several horizons are essentially identical with those given in the table, calculated to a CaO percentage of 2.06 and show the same relationship of horizon composition as the table of ratios and of molecular equivalent composition. In this case it is evident that the method of calculating out the accumulated alkaline earths was approximately correct, but it seems to have no advantage over the ratios used in the discussion of the Pedalfers or the calculation of the sesquioxides and silica to 100.

The percentage of sesquioxides is high and of silica is low in the parent drift when compared with the soil layers. It can not be stated on the basis of the data at hand whether this is wholly geological or in part pedological. No careful examination of the locality was made with reference to ground water, but nothing suggests its presence. In the absence of more specific information it is assumed that it is geological entirely.

No accumulation of sesquioxides in or above the carbonate zone has taken place. The neutral reaction of the several horizons shows that eluviation could not have taken place.

The composition of another profile of a Canadian Chernozem, from the Indian Head, Saskatchewan, experiment station farm, collected from an area of virgin soil, is shown in Table 153. The depth of sampling is the same as at the Krydor locality, the details of horizon thicknesses being slightly different.

TABLE 153.—*Composition of a Canadian Chernozem, Indian Head, Canada* [1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
33087	1	0–4	[a]60.51	0.52	5.11	12.74	0.090	2.00	1.65	2.17	0.79	0.34	0.20	13.75	99.87	0.430	------
			[b]70.15	.60	5.92	14.77	.110	2.31	1.91	2.51	.96	.39	.23	------	99.86	------	------
33088	2	4–20	[a]66.21	.52	5.25	12.85	.090	1.48	1.47	2.20	.96	.22	.09	8.72	100.06	.230	------
			[b]72.53	.57	5.75	14.18	.100	1.62	1.61	2.40	1.05	.24	.10	------	100.15	------	------
33089	3	20–30	[a]59.51	.51	5.21	12.79	.070	6.80	2.73	1.77	.89	.16	.07	9.65	100.16	.050	6.20
			[b]65.86	.56	5.76	14.11	.080	7.50	3.00	1.96	.98	.18	.08	------	100.07	------	------
33090	4	30–66	[a]52.40	.68	6.63	16.92	.123	5.04	3.67	2.30	.79	.16	.15	10.72	99.58	.050	4.45
			[b]58.69	.76	7.42	18.95	.140	5.64	4.10	2.57	.89	.18	.17	------	99.51	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
33087	1	0–4	0.8	2.3	1.9	9.5	6.8	43.7	35.2	100.2
33088	2	4–20	1.9	7.6	5.0	11.7	5.8	34.0	34.1	100.1
33089	3	20–30	1.2	6.1	4.3	11.6	5.4	28.0	43.9	100.5
33090	4	30–66	0	.3	.2	.9	1.4	18.3	79.4	100.5

[1] Collected by C. F. Marbut. [2] Analyzed by G. J. Hough and G. Edgington. [3] Analyzed by J. B. Spencer.

The sa and sf ratios and the molecular equivalent composition for silica and the sesquioxides are shown in Table 154. Since the accumulation of CaO and in some cases of MgO is large enough to be clearly shown by the complete analysis it seems to be unnecessary to determine the ba ratios or the combined molecular composition of the soil in alkalies and alkaline earths.

TABLE 154.—*Sample of a Canadian Chernozem, Indian Head, Canada*

Sample No.	Horizon	Depth in inches	Ratios sa	sf	ba	Molecular equivalent composition SiO₂	Fe₂O₃	Al₂O₃
33087	1	0–4	8.139	31.43	------	1.163	0.0308	0.1433
33088	2	4–20	8.763	33.42	------	1.203	.0360	.1376
33089	3	20–30	7.912	30.62	------	1.092	.0360	.1384
33090	4	30–66	5.265	20.96	------	.973	.0460	.1780

The sa and sf ratios show the same relationship between the composition of layer 4 and that of the higher layers as was shown in the sample from Krydor, Canada. The sa ratios for the first, second, and third layers differ slightly, that for layer 1 being lower than for 2, the reverse of what would be the case if podzolization had begun to operate on the surface soil. The differences between the ratios for layers 1 and 2 are consistent in this soil, both being larger in 2. It is well known from observation of incipient podzolization in the soils of the prairies of the United States that it manifests itself first at a depth of some inches from the surface rather than at the surface, where presumably the activity and effect of the resistance of grass to podzolization is greatest. It is possible that the higher sa and sf ratios for layer 2 may be an expression of incipient podzolization, though relative pH values do not indicate it.

The relation of the sa and sf ratios in layers 1, 2, and 3 to those in 4 are identical in kind with those in the Krydor profile though not exactly the same in magnitude. The ratios in 4 show a low percentage of silica as compared with the higher layers. The percentage of increase of alumina in 4, assuming that the lower ratio be due only to increased percentages of sesquioxides, over that in the higher layers is about 60, that of iron oxide is a little less, being about 50.

These percentages are much more nearly equal in amount than in the Krydor profile but they seem sufficiently different in this case to warrant the conclusion that there is no decrease in silica in the fourth layer but an increase of sesquioxides as was the case in the Krydor profile.

The molecular equivalent composition shows the same relationships between the several layers as do the sa and sf ratios.

A profile of Barnes silt loam from Moody County, S.Dak., has been sampled and analyzed, the results of chemical and mechanical analysis being shown in Table 155.

TABLE 155.—*Composition of Barnes silt loam, Moody County, S. Dak.* [1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
361435	1	0–2½	[a]66.73	0.54	4.26	10.10	0.13	1.71	0.87	1.95	0.93	0.23	0.27	13.60	101.32	0.460	------
			[b]77.10	.62	4.93	11.65	.15	1.98	1.01	2.25	1.08	.27	.31	------	101.35	------	------
361436	2	2½–8	[a]67.97	.61	4.42	11.50	.14	1.35	.87	1.83	1.01	.21	.27	10.05	100.23	.300	------
			[b]75.55	.68	4.91	12.78	.16	1.50	.97	2.03	1.12	.23	.30	------	100.23	------	------
361437	3	8–23	[a]71.40	.61	4.56	11.75	.25	1.14	1.08	2.01	1.16	.10	.14	5.42	99.62	.070	------
			[b]75.49	.64	4.82	12.42	.26	1.21	1.14	2.12	1.23	.11	.15	------	99.59	------	------
361438	4	23–47	[a]60.80	.40	3.46	8.98	.15	9.61	2.52	1.51	.96	.15	.16	11.05	99.80	.020	8.50
			[b]68.39	.45	3.89	10.10	.17	10.81	2.83	1.70	1.08	.17	.18	------	99.77	------	------
361439	5	47–60	[a]63.53	.45	3.70	9.40	.16	7.49	2.52	1.56	.79	.15	.12	9.75	99.62	.014	6.89
			[b]70.48	.50	4.10	10.43	.18	8.31	2.68	1.73	.88	.17	.13	------	99.59	------	------
361440	6	60–66	[a]63.65	.45	3.71	9.60	.18	7.43	2.50	1.61	.91	.15	.13	9.35	99.67	.020	6.92
			[b]70.26	.50	4.09	10.59	.20	8.20	2.76	1.78	1.00	.17	.14	------	99.69	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
361435	1	0–2½	0.5	2.8	3.9	8.2	6.5	46.1	31.9	99.9
361436	2	2½–8	.8	2.5	3.0	6.2	5.9	53.6	28.3	100.3
361437	3	8–23	1.6	3.9	4.6	10.1	9.7	44.0	25.9	99.9
361438	4	23–47	2.6	4.8	5.3	12.0	12.1	30.5	32.7	100.0
361439	5	47–60	2.3	5.2	6.1	13.7	12.2	31.0	29.6	100.1
361440	6	60–66	2.1	5.1	5.6	13.4	12.3	31.5	29.9	99.9

[1] Collected by W. I. Watkins. [2] Analyzed by G. J. Hough. [3] Analyzed by L. T. Alexander.

Horizon 4, as the profile was divided at the time the sample was collected, is the zone of carbonate accumulation. The maximum percentage of CaO, when the analyses have been calculated to mineral content, is 10.81, the percentage of CO_2 from carbonates being 8.50. It is apparent that the accumulated carbonates are mainly lime carbonates, the percentage of MgO in horizon 4 being 2.83 and in the parent glacial drift 2.76. The percentages of both lime and magnesia in horizons 1, 2, and 3 are very low compared with those in the accumulated horizons or in the parent glacial drift. The difference is much greater in this soil than in that of the Krydor, Canada, sample.

This sample is from near the eastern boundary of the Chernozem belt in South Dakota, where the rainfall is near the maximum for Pedocalic soil development in this latitude. The annual temperature is well above that of the Canadian locality of the preceding profile. The carbonates have been more completely removed from the horizons lying above that of carbonate accumulation, but this can not be definitely ascribed to the higher temperature of the locality. The accumulation of carbonate in layer 4 is definite, but the calcium carbonate is only about 24 per cent more than in the parent glacial drift. In the Krydor, Canada, profile the apparent concentration of carbonate is more than 400 per cent and in the Indian Head profile 33 per cent. The low concentration in the Moody County, S. Dak., sample can not be accepted as a standard for the Dakota latitude.

The carbonates have all been removed from the Dakota locality to a depth of 23 inches, but in the Krydor, Canada, locality to less than 14 inches, and at Indian Head, Canada, to a depth of 20 inches.

The several ratios, molecular equivalent composition, and silica and sesquioxides calculated to a total of 100 and to a constant percentage of CaO and MgO are shown in Table 156.

TABLE 156.—*Sample of Barnes silt loam, Moody County, S. Dak.*

Sample No.	Depth in inches	Ratios sa	sf	ba	Molecular equivalent composition SiO₂	Fe₂O₃	Al₂O₃	Percentage calculated to a total of 100 SiO₂	Fe₂O₃	Al₂O₃	Percentage calculated to constant percentages of CaO and MgO SiO₂	Fe₂O₃	Al₂O₃
361435	0 – 2½	11.25	41.24	------	1.278	0.0308	0.1140	82.30	5.26	12.43	77.10	4.93	11.65
361436	2½– 8	10.05	40.77	0.530	1.253	.0307	.1250	81.02	5.26	13.70	75.55	4.91	12.78
361437	8 –23	10.33	41.50	------	1.252	.0301	.1215	81.41	5.20	13.39	75.49	4.82	12.42
361438	23 –47	11.51	46.59	2.308	1.134	.0243	.0988	83.90	4.40	12.26	76.93	4.37	11.36
361440	60 –66	11.28	45.52	1.843	1.165	.0256	.1036	82.70	4.81	12.46	76.75	4.46	11.56

The relatively high sa and sf ratios for the thin surface layer is a feature characteristic of the Dark-Brown, Brown, and Gray soils but is not generally present in the Chernozems. It is probably caused by the action of wind and rain in washing and blowing the fine-grained material out of the thin surface layer, leaving the coarser material behind.

Both ratios are higher in the zone of carbonate accumulation and the parent material than in the higher layers. The sa ratio in the deeper horizons is a little more than 10 per cent higher than in layers 2 and 3. The sf ratio for the deeper layers is also higher than in 2 and 3 by almost exactly the same percentage as the sa ratio. This would suggest that it could be interpreted as a result of a decrease of silica. In the Canadian samples the two ratios did not show the same percentage of increase in the deeper layers over that in the higher, suggesting that in that case it must be due to concentration of the sesquioxides, or possibly to an increase of at least one of them and a decrease in silica.

The ratios show clearly that no shifting of sesquioxides has taken place from an A into a B horizon similar to that in the Podzolic soils.

The occurrence of the apparent concentration of sesquioxides in the layers of the soil where the carbonates are high could not be due to the concentration of carbonates alone, since the concentration of carbonates would affect both sesquioxides and silica alike in all the layers and would not, therefore, change the relationship of the ratios in the several layers after the carbonate concentration from what it was before. There has been concentration of sesquioxides in the deeper layers of the Canadian profiles and presumably also in the Dakota profile, though the ratios in the latter case show the possibility of explaining the facts by increase in silica.

When the composition of the whole soil is recalculated by eliminating the accumulated carbonates both of magnesium and of calcium and reducing the CaO to a percentage averaging about 1.50 of CaO and of MgO, 1.00, and the results are tabulated, they stand as shown in the last three columns of Table 156. In this case the percentages of silica for the two deeper layers is high, and those for both sesquioxides are low, indicating the accumulation of silica in these layers rather than of the sesquioxides.

The soil-developing processes at work have brought about an accumulation of organic matter, a very slight accumulation of calcium and potassium in the surface layer, the removal of carbonates from layers 1, 2, and 3, and the concentration of the same constituents in layer 4.

A profile of Moody silt loam from Moody County, S. Dak., was studied, sampled, and analyzed, the results being shown in Table 157.

TABLE 157.—*Composition of Moody silt loam, Moody County, S. Dak.* [1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
361401	1	0–2½	[a]64.20	0.68	4.27	11.20	0.13	1.34	0.86	2.12	0.83	0.24	0.28	14.52	100.67	0.080	------
			[b]75.03	.80	4.98	13.09	.15	1.57	1.01	2.48	.97	.28	.33	------	100.70	------	------
361402	2	2½–11	[a]65.51	.67	4.35	11.75	.10	1.31	.97	2.05	1.00	.21	.27	12.20	100.39	.400	------
			[b]74.62	.76	4.95	13.37	.11	1.49	1.10	2.43	1.14	.24	.31	------	100.42	------	------
361403	3	11–22	[a]68.19	.70	5.00	12.56	.10	1.04	1.08	2.15	1.00	.19	.19	7.82	100.02	.180	------
			[b]73.95	.76	5.42	13.62	.11	1.13	1.17	2.33	1.08	.21	.21	------	99.99	------	------
361404	4	22–30	[a]70.46	.70	4.83	12.87	.12	1.40	1.41	2.13	1.14	.18	.18	4.85	100.27	.050	------
			[b]74.06	.74	5.08	13.52	.13	1.47	1.48	2.21	1.20	.19	.19	------	100.30	------	------
361405	5	30–57	[a]58.70	.57	3.62	9.90	.10	9.60	2.90	1.67	.94	.19	.15	11.80	100.14	.008	8.70
			[b]66.54	.65	4.10	11.22	.11	10.88	3.29	1.89	1.07	.22	.17	------	100.14	------	------
361406	6	57–66	[a]63.74	.57	3.70	10.45	.10	6.42	2.96	1.83	1.05	.18	.14	9.67	100.81	.014	6.10
			[b]70.53	.63	4.08	11.56	.11	7.11	3.28	2.03	1.16	.20	.15	------	100.84	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
361401	1	0–2½	1.3	0.5	0.3	0.9	3.9	55.8	37.2	99.9
361402	2	2½–11	.5	1.8	1.1	2.1	4.7	61.5	28.5	99.8
361403	3	11–22	.2	.7	.4	.6	2.4	59.9	35.4	99.6
361404	4	22–30	.0	.1	.2	.7	4.8	60.2	33.9	99.9
361405	5	30–57	.5	.5	.2	.6	7.2	63.8	27.2	100.0
361406	6	57–56	.0	.2	.2	.5	17.2	59.2	22.7	100.0

[1] Collected by W. I. Watkins. [2] Analyzed by G. J. Hough. [3] Analyzed by L. T. Alexander.

The Moody soils differ from the Barnes soils in their derivation from loesslike material rather than from glacial drift as are the Barnes soils. The composition in actual weight percentages of the two soils is very nearly the same and the relationships of the several horizons within each are identical, though the top of the carbonate zone is a little deeper in the Moody than in the Barnes soil.

Barnes silt loam contains from 12 to a little more than 20 per cent of sand coarser than very fine sand, but Moody silt loam has a maximum of 5 per cent and the content of very fine sand is only about half as high as in the Barnes soil. The percentage of silt in Barnes silt loam, however, ranges between 25 and 30 and in Moody silt loam between 56 and 64.

The percentages of silica run higher in Barnes silt loam than in Moody silt loam, but those of iron oxide and alumina are correspondingly lower.

The percentages of alkalies and alkaline earths are much alike, layer for layer, in both soils.

The several ratios, molecular equivalent composition, and silica and sesquioxides calculated to a total of 100 and to a constant percentage of CaO and MgO are shown in Table 158.

TABLE 158.—*Sample of Moody silt loam, Moody County, S. Dak.*

Sample No.	Depth in inches	Ratios			Molecular equivalent composition			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO (1.50) and MgO (1.00)		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
361401	0–2½	9.74	39.92	0.546	1.244	0.03117	0.1280	80.16	5.46	14.37	75.08	4.98	13.10
361402	2½–11	9.48	39.95	.540	1.237	.03100	.1308	80.28	5.32	14.40	74.66	4.95	13.38
361403	11–22	9.23	36.17	.467	1.226	.03390	.1332	79.52	5.82	14.65	73.87	5.43	13.65
361404	22–30	9.31	38.63	.524	1.228	.03180	.1322	79.64	5.46	14.54	74.39	5.10	13.57
361405	30–57	10.08	43.00	2.106	1.163	.02570	.1097	81.28	5.00	13.70	75.33	5.80	12.70
361406	57–66	10.37	45.89	1.476	1.170	.02550	.1131	81.85	4.73	13.41	76.57	4.62	13.09

The molecular equivalent composition indicates a lower number of molecules of silica per unit of weight in layers 5 and 6 than in any other layer. The sa and sf ratios are higher in these two layers than in any of the others. The apparent contradiction is brought about because of the high percentage of CaO and MgO in the two layers. The ratios are independent of the percentages of these constituents present.

The percentages of SiO_2, Fe_2O_3, and Al_2O_3 computed to a total of 100 eliminate the influence of these substances, and so also do the percentages of SiO_2, Fe_2O_3, and Al_2O_3 calculated to a constant percentage of CaO and MgO. In all cases where the influence of the high percentages of CaO and MgO are eliminated, a higher amount of silica is indicated for layers 5 and 6 than for the other layers. The amount in 6 is somewhat larger than in 5. This may be a feature of the parent material or it may be a soil feature. The same relationship is shown in the Krydor, Canada, profile.

If the silica in the solum be dissolved because of the alkaline soil solution, it would be deposited in the zone of carbonate accumulation and in the layer immediately below it. Whether this is an expression of this action of the soil solution can not be definitely proved from the data available, but the suggestion is of some interest.

A profile at Holdrege, Nebr., whose chemical and mechanical composition are shown in Table 159, lying in the Chernozem belt but not sampled below the carbonate zone, is identical in its essential solum features with those just described.

TABLE 159.—*Composition of Holdrege silt loam, Holdrege, Nebr.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34709	1	0–6	[a] 71.73	0.55	2.78	11.34	0.05	1.68	0.84	2.51	1.04	0.20	0.02	7.26	100.00	0.190	------
			[b] 77.33	.59	3.00	12.23	.05	1.81	.91	2.71	1.12	.22	.02	------	99.99	------	------
34710	2	6–16	[a] 71.87	.53	3.10	12.60	.05	1.56	1.03	2.68	1.07	.19	.02	5.20	100.00	.100	------
			[b] 75.89	.56	3.27	13.31	.05	1.65	1.09	2.83	1.13	.20	.02	------	100.01	------	------
34711	3	16–28	[a] 71.58	.54	3.25	12.72	.05	1.52	1.18	2.82	1.00	.21	.02	5.11	100.00	.050	------
			[b] 75.43	.57	3.42	13.40	.05	1.60	1.24	2.97	1.05	.22	.02	------	99.97	------	------
34712	4	28–43	[a] 70.14	.55	3.43	12.53	.04	3.41	1.60	2.81	.98	.22	.02	4.27	100.00	.030	------
			[b] 73.30	.57	3.58	13.09	.04	3.56	1.67	2.93	1.02	.23	.02	------	100.01	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34709	1	0–6	0.1	0.2	0.1	0.5	8.5	65.0	25.6	100.0
34710	2	6–16	0	.1	.1	.1	9.5	58.2	31.8	99.8
34711	3	16–28	0	.0	.1	.3	7.8	56.6	35.3	100.1
34712	4	28–43	0	.1	.0	.3	9.1	68.2	22.3	100.0

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Mar. 15, 1918.
[3] Analyzed by L. T. Alexander.

The concentration of carbonate is not high, this being a feature found to be consistent throughout the United States in soils developed from loess. The Pedocals in Kansas and farther south seem to show slight accumulation of silica in the surface soil, but even in these places it may be the product of wind shifting of material through a long period of time.

The sa and sf ratios, the molecular equivalent composition, the composition in SiO_2, Fe_2O_3, and Al_2O_3, when recalculated to a CaO percentage of 1.50 throughout all the horizons and a MgO percentage of 1.00, and the percentages of SiO_2, Fe_2O_3, and Al_2O_3 calculated to a total of 100 are shown in successive parts of Table 160. The sa and sf ratios are smaller in the carbonate-accumulation layer and the layer beneath than in the overlying layers.

TABLE 160.—*Sample of Holdrege silt loam, Holdrege, Nebr.*

Sample No.	Depth in inches	Ratios			Molecular equivalent composition			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO (1.50) and MgO (1.00)		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
34709	0–6	10.75	60.61	--------	1.282	0.01878	0.1196	83.54	3.24	13.21	77.23	2.99	12.21
34710	6–16	9.69	61.50	--------	1.258	.02047	.1302	82.07	3.53	14.39	75.81	3.26	13.29
34711	16–28	9.90	58.44	--------	1.251	.02141	.1311	81.76	3.70	14.52	75.43	3.42	13.40
34712	28–43	9.52	54.25	--------	1.215	.02242	.1280	81.57	3.95	14.47	75.09	3.67	13.41

The composition computed to uniform CaO and MgO percentages shows uniformity in composition in the layers above the carbonate zone and high silica in the surface horizon and slightly decreasing silica downward. This relationship is clearly shown in the sa ratio, in the molecular equivalent composition, and in the silica when the composition of the soil in SiO_2, Al_2O_3, and Fe_2O_3 is computed to 100.

Both iron oxide and alumina increase downward, this, as well as the decrease in silica, being reflected in sa and sf ratios, the increase in iron oxide being especially marked.

The Barnes and Moody soils lie in the Dakotas, northeastern Nebraska, northwestern Iowa, and southwestern Minnesota. The Barnes soils, developed from Wisconsin glacial till, do not extend south of the Missouri River from South Dakota. The greater part of the soils of the Chernozem belt of Nebraska have developed from silty material different in character from that from which the Moody soils have developed. Large areas of Nebraska soils have profiles diverging in character from the normal Chernozem profile because of the presence of a heavy clay subsoil. These are described as Crete soils.

West of the longitude of Hastings, Nebr., the soils with heavy clay subsoils cover small areas and finally disappear almost entirely from the well-drained silty uplands in the vicinity of Holdrege, Nebr. In this region, the western part of the Chernozem belt in Nebraska, the dominant soil is Holdrege silt loam, described on page 73.

Two profiles were sampled from the Kansas part of the Chernozem belt, one from near Olmitz, the other from near Jetmore. In both cases the soil was sampled to the carbonate zone only. The chemical and mechanical composition of material from the Olmitz profile are shown in Table 161, and of that from the Jetmore profile in Table 162.

TABLE 161.—*Composition of Chernozem, Olmitz, Kans.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29888	1	0–4	[a] 73.49	0.54	2.72	10.83	0.063	1.27	0.71	2.54	1.55	0.13	0.22	5.81	99.87	0.176	------
			[b] 78.05	.57	2.89	11.50	.067	1.35	.75	2.70	1.65	.14	.23	------	99.90	------	------
29889	2	4–22	[a] 72.83	.60	3.08	12.00	.072	1.16	.86	2.62	1.46	.12	.14	4.99	99.93	.160	------
			[b] 76.63	.63	3.24	12.62	.076	1.22	.90	2.76	1.54	.13	.15	------	99.90	------	------
29890	3	22–32	[a] 68.71	.55	4.22	14.66	.069	1.37	1.58	2.55	1.38	.11	.13	4.29	99.62	.059	------
			[b] 71.79	.57	4.41	15.32	.072	1.43	1.65	2.66	1.44	.11	.14	------	99.59	------	------
29891	4	30+	[a] 67.75	.58	3.93	13.83	.073	2.93	1.59	2.50	1.42	.13	.12	4.71	99.56	.041	1.16
			[b] 71.10	.61	4.12	14.52	.077	3.07	1.67	2.62	1.49	.14	.13	------	99.55	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29888	1	0–4	0.0	0.0	0.0	0.5	30.5	45.1	23.8	99.9
29889	2	4–22	0	0	0	.6	35.2	35.0	28.9	99.7
29890	3	22–32	0	0	0	.5	26.8	28.9	43.5	99.7
29891	4	30+	0	0	0	.3	21.4	37.7	40.3	99.7

[1] Collected by C. F. Marbut. [2] Analyzed by G. Edgington. [3] Analyzed by J. B. Spencer.

TABLE 162.—*Composition of Chernozem, Jetmore, Hodgeman County, Kans.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29864	1	0–5	[a] 74.49	0.66	2.70	10.77	0.070	1.29	0.91	2.85	1.30	0.16	0.08	6.25	99.53	0.180	------
			[b] 77.32	.70	2.88	11.49	.070	1.38	.97	3.04	1.39	.17	.09	------	99.51	------	------
29865	2	6–18	[a] 69.83	.67	3.97	12.87	.070	1.34	1.17	3.04	1.11	.16	.07	5.40	99.70	.110	------
			[b] 73.82	.71	4.19	13.60	.070	1.42	1.24	3.21	1.17	.17	.07	------	99.67	------	------
29866	3	18–30	[a] 68.05	.58	4.25	14.18	.071	2.12	1.55	2.76	1.19	.16	.18	4.98	100.07	.050	0.62
			[b] 71.56	.61	4.47	14.93	.075	2.23	1.63	2.90	1.25	.18	.21	------	100.05	------	------
29867	4	30+	[a] 68.23	.55	4.08	13.81	.077	2.50	1.48	2.75	1.20	.17	.20	4.84	99.89	.032	.81
			[b] 71.70	.58	4.29	14.52	.081	2.63	1.55	2.89	1.26	.18	.21	------	99.89	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29864	1	0–5	0.0	0.0	0.3	2.0	19.5	52.1	26.3	100.2
29865	2	6–18	0	.1	.1	.5	15.4	53.9	31.0	100.0
29866	3	18–30	0	.0	.1	.3	15.2	40.1	44.5	100.2
29867	4	30+	0	.0	.0	.7	19.6	38.7	41.3	100.3

[1] Collected by C. F. Marbut. [2] Analyzed by G. J. Hough and G. Edgington. [3] Analyzed by J. B. Spencer.

In both cases, the silica in the surface soil, to a depth of 4 and 5 inches, respectively, is a little higher than in the layers below, in the Jetmore sample the difference being 3.5 per cent but in the Olmitz sample only about 1.5 per cent. The percentage of CaO in the carbonate zone above that in the overlying layers is slight in both cases, but it is definite.

The dark-colored layer is thick, the percentage of organic matter in the upper part being about 5. This is only about half the percentage of organic matter in the Barnes and Moody soils, but only a little less than that in Holdrege silt loam.

The percentage of clay in the layer immediately overlying the carbonate-accumulation layer is nearly twice as high as in the overlying layers and a little higher than that of the carbonate layer. In the Moody and Barnes soils the range of differences in the several layers is very slight; that in Holdrege silt loam is a little higher than in the other two soils but much lower than in the soils at Jetmore and Olmitz. The latter soils have developed from material derived from the underlying shales, limestones, and sandstones, with probably some shifting and mixing by wind, whereas the Moody, Barnes, and Holdrege soils have developed from material transported considerable distances.

The sa and sf ratios and the results of recalculations of SiO_2, Fe_2O_3, and Al_2O_3 to a basis of 100 as well as to a constant percentage of CaO and MgO (tables 163 and 164) bring out this higher clay (Al_2O_3) content in the deeper layers of the Olmitz and Jetmore soils. The sf ratio shows a higher percentage of iron oxide in these layers as well as of alumina, the increased percentage over that in layer 2 being 9, whereas that of alumina is 12.

TABLE 163.—*Sample of a Chernozem soil, Olmitz, Kans.*

Sample No.	Horizon	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
29888	1	0- 4	11.53	71.56	----------	85.50	3.12	12.44	78.16	2.89	11.52
29889	2	4-22	10.32	62.67	----------	82.85	3.50	13.64	76.76	3.24	12.64
29890	3	22-32	7.96	43.14	----------	78.44	4.82	16.74	72.60	4.46	15.49
29891	4	30+	8.32	45.73	----------	79.23	4.60	16.18	73.14	4.24	14.93

TABLE 164.—*Sample of a Chernozem soil, Jetmore, Hodgeman County, Kans.*

Sample No.	Horizon	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
			sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
29864	1	0- 5	11.44	71.14	----------	84.33	3.14	12.42	77.36	2.88	11.50
29865	2	6-18	9.23	46.68	----------	80.58	4.57	14.83	74.01	4.20	13.63
29866	3	18-30	8.15	42.42	----------	78.67	4.91	16.41	72.62	4.53	15.15
29867	4	30+	8.39	44.04	----------	79.21	4.74	16.04	73.00	4.37	14.78

The percentage of silica, when silica and both the sesquioxides have been calculated to a total of 100, in layer 3 is lower than that in 2 by an amount somewhat larger than is the higher percentage of alumina in 3 than in 2, but the insufficiency of the alumina to account for the decrease in silica is fully made up by the higher percentage of iron oxide in 3, making it probable therefore, that the difference in composition is the result of an accumulation of alumina in layer 3, with slight accumulation of iron oxide, rather than to a decrease in silica.

The field characteristics as well as the pH values make an explanation of the difference by podzolization practically out of the question. The position of the layer of clay accumulation also makes such an explanation very questionable. When the amount of difference is so small as here, showing slight development, it seems practically certain that accumulation by podzolization would have taken place in layer 2.

Although no exchangeable base determinations have been made to confirm the suggestion, it seems that the concentration is most simply and easily explained as the result of the presence of a very small amount of sodium salts. Incipient salinization has taken place. This conclusion is confirmed to a certain extent by the known fact that clay concentration is a highly characteristic feature of the soils derived from residual material east of this region, where the parent rocks are lithologically somewhat similar.

In all these profiles, and in those of the Pedocals in general, the percentage of alkalies and alkaline earths is high, especially when the percentage of these constituents in the Pedalfers is taken as a standard. The percentage of organic matter, indicated both in the loss on ignition and in the percentage of nitrogen, is high when the thickness of the layer containing it is considered. In the Pedalfers the layer is very thin, in few places amounting to more than 3 inches, whereas in the Chernozems it ranges up to nearly 2 feet. In the Moody and Barnes soils the percentage of nitrogen is relatively high to a depth of 23 inches and in the sample from Jetmore, Kans., to a depth of 18 inches. South of this point the thickness of the layer decreases.

The high plains of Texas lie within the Chernozem belt. The northwestern part of the State lies in the transition zone where the Brown soils of the northern plains change to the Red and Reddish soils (subsoils) of the southern plains. In the vicinity of Amarillo the soils developing on slopes, where a considerable part of the rainfall is lost by run-off, have subsoils with a well-defined yellowish-red color, and those of the soils lying on flat surfaces are brown.

The dominant soils in this region were mapped and defined as members of the Amarillo series about 20 years ago, but during the last few years the detailed work demanded by modern conditions has made it necessary to separate the red from the brown members. The red members have been given recognition as a distinct series under the name of Amarillo and the brown members as Pullman. The Pullman soils have been carefully studied in the field by Mr. E. H. Templin, of the Texas Agricultural Experiment Station, who collected samples from a well-developed typical profile, except of the layers below a depth of 40 inches, which were subjected to a searching investigation by Anderson and Byers (*1*) in the laboratories of the Bureau of Chemistry and Soils, United States Department of Agriculture. In a publication containing the results of this work, the soil is described as Amarillo, the texture of the surface horizon being a clay loam, but as stated above it is the brown rather than the red soil of the region. The brown soils seem to be the normal soils of the region, the red soils representing soils normally belonging farther south where development has taken place on smooth surfaces but under the influence of higher temperature than that prevailing in the region of Amarillo. The higher temperature renders the rainfall less effective than it would otherwise be, the soil is drier, oxidation has been more effective, and the subsoil has become red or reddish. The same result has been effected on the slopes in the Amarillo region because of the low moisture supply due to run-off.

The chemical and mechanical composition of a sample of Pullman clay loam, Amarillo, Potter County, Tex., are shown in Table 165.

TABLE 165.—*Composition of Pullman clay loam, Amarillo, Potter County, Tex.*[1]

Sample No.	Horizon	Depth	Chemical[2]											Ignition loss	Total	N	CO_2 from carbonates
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3				
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
35937	1	0- 5	[a]75.62	0.78	3.16	10.56	0.09	0.67	0.78	2.20	1.06	0.10	0.07	4.98	100.07	------	------
			[b]79.58	.82	3.32	11.11	.10	.70	.82	2.31	1.11	.11	.07		100.05	------	------
			[c]50.51	.56	8.80	22.04	.14	1.48	2.08	2.68	.06	.20	.18	12.08	100.81	------	0
			[d]57.56	.63	10.00	25.07	.16	1.68	2.35	3.02	.07	.23	.20		100.97	------	------
35916	2	10- 20	[a]70.48	.71	4.40	13.88	.09	.97	1.35	2.56	1.01	.09	.07	4.94	100.55	------	------
			[b]74.14	.75	4.62	14.59	.10	1.02	1.42	2.69	1.06	.09	.07		100.55	------	------
			[c]51.51	.57	8.61	22.71	.09	1.59	2.66	2.54	.01	.12	.14	9.50	100.05	------	0
			[d]56.91	.61	9.56	25.22	.10	1.73	2.92	2.79	.01	.13	.15		100.13	------	------
35917	3	30- 40	[a]68.72	.74	4.31	13.25	.08	2.64	1.37	2.48	1.03	.10	.06	5.50	100.28	------	------
			[b]72.72	.78	4.56	14.54	.09	2.79	1.45	2.62	1.09	.10	.06		100.80	------	------
			[c]51.32	.58	8.46	22.43	.05	2.27	2.80	2.50	.06	.14	.14	10.19	100.94	------	.35
			[d]57.14	.65	9.43	25.07	.05	2.55	3.15	2.80	.07	.16	.15		101.22	------	------
35918	4	54- 64	[a]74.49	.95	3.83	11.67	.06	1.09	1.10	2.14	.87	.07	.21	3.82	100.30	------	------
			[b]77.45	.99	3.98	12.42	.06	1.13	1.14	2.22	.90	.07	.22		100.58	------	------
			[c]51.23	.55	8.19	24.08	.07	1.73	2.83	2.42	.10	.11	.13	8.72	100.46	------	0
			[d]56.12	.60	8.90	26.17	.07	1.88	3.07	2.63	.11	.12	.14		99.81	------	------
35919	5	70- 75	[a]40.72	.42	2.04	6.69	.04	25.80	1.06	1.20	.46	.08	.13	21.82	100.46	------	------
			[b]52.07	.54	2.61	8.21	.04	33.00	1.35	1.53	.59	.10	.16		100.20	------	------
			[c]38.42	.37	5.71	17.64	.06	16.38	2.52	1.83	.06	.09	.10	17.85	101.03	------	11.22
			[d]46.77	.45	6.95	21.47	.07	19.94	3.07	2.23	.07	.11	.12		101.25	------	------
----------	6	96-100	[a]56.71	.57	2.86	9.26	.06	14.11	1.22	1.71	.73	.09	.11	13.00	100.43	------	------
			[b]65.19	.65	3.29	10.64	.06	16.22	1.40	1.96	.83	.10	.12		100.46	------	------
			[c]45.48	.52	6.89	20.09	.05	9.05	2.87	2.26	.01	.11	.13	12.41	99.87	------	5.87
			[d]51.92	.59	7.86	22.38	.05	10.33	3.27	2.58	.01	.12	.14		99.25	------	------

[1] Collected by E. H. Templin. [2] Analyzed by G. J. Hough and G. Edgington.

TABLE 165.—*Composition of Pullman clay loam, Amarillo, Potter County, Tex.*—Continued

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
35937	1	0- 5	0.0	0.2	0.3	2.6	12.1	55.1	27.6	97.9
35936	2	10- 20	.0	.1	.2	1.9	8.3	41.0	47.4	98.9
35917	3	30- 40	1.0	.5	.4	1.6	6.9	45.2	43.8	99.4
35918	4	54- 64	.1	.3	.4	3.4	16.6	41.2	37.9	99.9
35919	5	70- 75	.1	.4	.4	2.2	9.2	34.1	53.4	99.8
----------	6	96-100	.2	.2	.3	2.1	12.2	41.0	44.0	100.0

[3] Analyzed by L. T. Alexander and H. W. Lakin.

The complete analysis shows an apparent concentration of silica in the upper 5 inches and a correspondingly low percentage of other constituents. It is apparent that two zones of carbonate accumulation are present, one lying between depths of 30 and 40 inches, the other between 70 and 75 inches. The latter is much more highly concentrated, and the material beneath it, extending from 96 to 100 inches, has a high percentage of carbonates. Field work in the region shows the presence of a buried soil, but the available information is not entirely clear as to whether field conditions show its presence at the locality where this sample was collected. The chemical analysis indicates it so strongly, however, that it may be assumed to be present. The zone of accumulation in the new soil extends from 30 to 40 inches in depth and has attained faint concentration only. The percentage of calcium oxide, however, is more than twice as high as that in the material both below and above it. The zone extending from 54 to 64 inches may be considered the A, or surface, horizon of the buried soil whose zone of accumulation extends from 70 to 75 inches.

A calculation of the analyses on the basis of a constant percentage, throughout all layers of the profile, of CaO and MgO, limiting the CaO and the MgO to constant percentages, gives the results for the silica and sesquioxides shown in Table 166.

TABLE 166.—*Sample of Pullman clay loam, Amarillo, Potter County, Tex.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
35937	0- 5	12.17	63.52	----------	84.65	3.53	11.82	69.02	2.88	9.63
35916	10- 20	8.63	40.36	----------	79.42	4.94	15.63	64.24	4.00	12.64
35917	30- 40	8.50	42.04	----------	79.19	4.96	15.83	63.98	4.01	12.79
35918	54- 64	10.60	51.67	----------	82.52	4.24	13.23	67.34	3.46	10.80
35919	70- 75	10.78	52.87	----------	82.79	4.15	13.05	63.00	3.15	9.93
----------	96-100	----------	52.50	----------	84.09	4.24	11.66	65.45	3.30	9.25

In Table 165 the upper 3 layers constitute the modern soil, the lower 3 the old (buried) soil. In the upper 3 it is clear that silica has accumulated in the topmost 5 inches. This can be most simply explained as the product of wind action in removing the finer particles and leaving the coarser behind, these being made up of a larger proportion of quartz. The very slight acidity of the surface layer seems not to have caused any eluviation that can be shown by the analysis.

Table 166 shows the twofold character of the profile even more clearly than Table 165. They both show also the lack of eluviation, unless the accumulation of silica in the surface horizon be caused by it, but that is more easily explained as already stated.

Colloidal material was extracted from each of the horizons of the Pullman (Amarillo) soil and discussed by Anderson and Beyers (*1*) in the paper already referred to. The composition of the colloid shows the same twofold character of the profile, but less strikingly than the whole soil. The lack of podzolization is equally clear and the sa ratios are high as was expected, though much lower than those of the whole soil because of the absence of quartz from the colloid, or if present at all in very small quantity.

The chemical composition of material from a profile of a Chernozem near Paducah, Tex., is shown in Table 161. The zone of carbonate accumulation, extending from 17 to 40 inches, is well developed, the percentage of CaO being 16, whereas that in the underlying parent material, consisting of disintegrated reddish sandy shales, is a little less than 4. The top of the carbonate zone lies at a depth of 12 inches, but the greatest concentration begins at a depth of 17 inches.

TABLE 167.—*Chemical composition of Vernon clay loam, Paducah, Tex.*[1 2]

Sample No.	Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4457a	1	0-12	[a]74.53	0.62	3.27	11.00	0.04	1.70	1.41	2.57	1.14	0.05	0.11	4.45	101.89	0.090	------
			[b]78.00	.65	3.42	11.51	.04	1.78	1.48	2.69	1.19	.05	.12	------	100.93	------	------
4457b	2	12-17	[a]68.47	.67	3.27	10.63	.03	5.07	1.43	2.45	1.02	.06	.09	6.73	99.92	.060	------
			[b]73.42	.72	3.50	11.39	.03	5.43	1.53	2.62	1.09	.06	.10	------	99.89	------	------
4457c	3	17-40	[a]56.42	.58	2.75	8.42	.03	14.00	1.84	2.18	1.23	.11	.13	12.75	100.44	.020	------
			[b]64.63	.66	3.15	9.67	.03	16.03	2.11	2.50	1.41	.13	.15	------	100.47	------	------
4457d	4	40-55	[a]70.00	.67	3.40	10.68	.03	3.74	2.40	2.85	1.70	.13	.11	4.55	100.26	.020	------
			[b]73.33	.70	3.56	11.19	.03	3.92	2.51	2.99	1.78	.14	.12	------	100.27	------	------

[1] Collected by C. F. Marbut. [2] Analyzed by G. J. Hough.

The percentage of SiO_2 in the 12-inch surface layer is about 4.5 higher than in the underlying layer. When layers 2 and 3 are calculated to the same percentage of CaO (1.78) as is present in layer 1, the percentages of silica for the 3 horizons are 78, 76.2, and 75.37, respectively. This indicates that no eluviation has taken place, the difference being probably due to the shifting of sand on the removal of fine material from the surface by wind.

The results obtained by recalculating the silica and sesquioxide percentages to a total of 100, to a constant percentage of CaO and MgO, and the sa and sf ratios are shown in the several parts of Table 168.

TABLE 168.—*Sample of a Chernozem soil, Paducah, Tex.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
4457a	0-12	11.52	60.44	----------	83.93	3.68	12.37	77.78	3.41	11.47
4457b	12-17	10.95	55.59	----------	83.14	3.96	12.88	76.43	3.64	11.86
4457c	17-40	11.36	54.37	----------	83.44	4.06	12.48	76.16	3.71	11.39
4457d	40-55	11.13	54.58	----------	83.25	4.04	12.40	75.93	3.68	11.57

The silica-alumina (sa) ratios, calculated on the composition of the whole soil reduced to a loss-free basis, for the four layers are 11.52, 10.95, 11.36, and 11.13. Layer 4 being true parent material, these ratios give a result for the latter so very little lower than that in the other layers that it seems doubtful whether any significance can be attached to it. The rocks in the region lie essentially horizontal so that a slight difference in composition between those which furnished what is being designated here as parent material and those from which the solum layers were developed could easily account for the slightly lower ratio in layer 4.

The percentages of silica and sesquioxides calculated to 100 and also to constant CaO and MgO are in each case so strikingly uniform that further discussion is wholly unnecessary. It is evident that eluviation has not taken place nor has there been accumulation of silica except the slight accumulation suggested by the higher percentage of SiO_2 in the surface layer. It is apparent that this, like the same feature in the preceding Pedocal profiles, is most easily explained as the product of wind and rain-beating action.

The dominant soil in the Lubbock region is reddish below the surface horizon of organic-matter accumulation, and in this latitude and southward the dark-colored surface layer is dark brown.

These soils are associated with darker colored soils, the Richfield soils, which have brown rather than red subsoils and a zone of carbonate accumulation at a depth ranging from 18 to 28 inches. They occupy flats and a very great number of slight depressions ranging from about 6 to 8 inches in depth. The soil profile contains no heavy clay layer suggesting the presence of a Solonetzlike profile. The depressions, therefore, can not have been caused by the same processes as those producing the usual depressions of Solonetz soils.

FIGURE 57.—Profile of Richfield clay loam near Lubbock, Lubbock County, Tex.

The larger amount of moisture these soils receive, whether they occur on flat areas or depressions, has caused a more luxuriant growth of grass than that on the associated Amarillo soils, giving them a darker color.

The western part of Lubbock County, Tex., lies on the Llano Estacado, or high plains, and the eastern part on the rolling plains east of the high plains escarpment. The surface on the high plains is very smooth, almost flat over large areas, but there are a large number of small shallow depressions which seem to be the result of settling because of removal of underground material, presumably calcium carbonate. The character of the soil within them shows that these basins are entirely different from the Solonetz microrelief basins on the Russian steppes and the slick spots of our own dry regions. The soils in these basins are very dark, almost black, the profile being essentially the same as that of the Pullman soils of the Amarillo region, though, so far as is now known, the modern soil does not cover an old buried soil. The soils on the slightly higher lying land around these basins are dark brown but much less dark than those in the basins. The former have reddish layers beneath the dark-colored layer, whereas the corresponding layer of the basin soils is brown. A well-defined carbonate-accumulation zone lies at a depth of 18 inches.

The dark-colored basin soil is similar to the Chernozems of Kansas, and the soils on the higher areas fit more nearly into the local environment. The dark-colored basin soils have a considerably higher total moisture supply than the redder soils since they receive moisture lost by the higher lying soils through drainage. The basin soils support a more vigorous growth of grass, and the subsoils have been less oxidized and dehydrated.

The composition of material from a profile of the dark-colored soils from near Lubbock, Lubbock County, Tex., is shown in Table 169. No material from the parent material beneath the carbonate zone was collected. Figure 57 shows a block of typical Richfield clay loam taken in this locality.

TABLE 169.—*Composition of Richfield clay loam, Lubbock County, Tex.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34764	1	0–10	a 79.64	0.52	2.74	8.27	0.03	0.63	0.87	1.82	1.12	0.10	0.070	4.18	100.00	------	------
			b 83.09	.54	2.86	8.36	.03	.66	.91	1.91	1.17	.10	.070	------	99.97	------	------
34765	2	10–18	a 78.97	.46	2.89	9.12	.02	.78	1.10	1.75	.72	.04	.050	4.10	100.00	------	------
			b 82.33	.48	3.01	9.51	.02	.81	1.15	1.82	.75	.04	.050	------	99.97	------	------
34766	3	18–25	a 55.66	.43	2.72	8.45	.03	14.09	1.67	1.34	.30	.09	.003	15.22	100.00	------	------
			b 65.66	.51	3.21	9.97	.04	16.62	1.92	1.58	.35	.11	.004	------	99.97	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34764	1	0–10	0.0	0.2	3.2	19.3	21.8	25.4	30.0	99.9
34765	2	10–18	.0	.2	3.0	18.2	18.1	23.7	36.8	100.0
34766	3	18–25	.1	.4	2.6	15.2	14.0	21.8	46.0	100.1

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Feb. 15, 1918.
[3] Analyzed by H. W. Lakin.

The percentages of alumina and iron oxide are both moderately low, and that of alumina in the carbonate zone is a little higher than in the higher layers, despite the presence of 16 percent of CaO.

The results of recalculation of the percentages of silica and the two principal sesquioxides, both to a total of 100 and to a uniform composition, in all horizons, of a constant percentage of CaO and MgO are shown in Table 170. The sa and sf ratios are shown as part of the same table.

TABLE 170.—*Sample of a Chernozem soil, Lubbock County, Tex.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
34764	0–10	16.89	20.00	--------	89.16	3.03	8.86	82.73	2.84	8.33
34765	10–18	14.71	72.48	--------	86.80	3.17	10.01	81.79	2.99	9.44
34766	18–25	11.19	54.19	--------	83 28	4.07	12.64	78.67	3.84	11.94

The recalculated tables and the ratios show a content of silica in the carbonate layer lower than in the overlying layer. The low percentages in the two sections showing the recalculated composition in SiO_2, Fe_2O_3, and Al_2O_3 indicate that there is at least no increase of silica in this layer, and the high percentage of alumina in both sections, for this layer, together with the low sa ratio, make it clear that a higher percentage of alumina is actually present. This is a relationship entirely different from that in the other Chernozems. In those previously examined there is certainly no lower percentage of silica than in the higher layers, and there is some indication in most of the soils that it is actually higher. The higher percentage of alumina in the carbonate zone is equally unusual. The only suggested reason for this is the presence of a rather deep Solonetz layer regarding which field evidence is not available.

The eastern part of the Chernozem belt in Nebraska and Kansas includes soils with heavy-clay layers in the lower part of the solum, which are usually described as claypan soils. In Nebraska they have developed from silty materials identified by Nebraska geologists as loess. In Kansas they have developed from the products of disintegration of shales and limestones. The shales are usually more or less calcareous. The composition of a sample of soil from Belleville, Republic County, Kans., belonging in this group, but in which the claypan is not highly developed, has been described on page 68.

The composition of material from a profile of this kind from Fairmont, Fillmore County, Nebr., is shown in Table 171. The locality from which the sample was taken is near the eastern boundary of true Chernozem soils in which the carbonate zone, as a zone of accumulation, is very slightly developed.

TABLE 171.—*Composition of Crete silt loam, Fairmont, Fillmore County, Nebr.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
32395	1	0– 6	a 71.47	0.61	3.30	10.87	0.060	1.24	0.80	2.39	1.36	0.17	0.08	7.35	99.70	0.210	------
			b 77.13	.66	3.56	11.73	.060	1.34	.94	2.58	1.47	.18	.09	------	99.74	------	------
32396	2	6–15	a 71.54	.69	3.47	11.34	.060	1.13	.70	2.22	1.22	.17	.08	7.20	99.80	.200	------
			b 77.09	.72	3.74	12.22	.060	1.22	.75	2.39	1.31	.18	.09	------	99.77	------	------
32397	3	15–36	a 65.43	.62	5.69	15.26	.060	1.29	1.31	2.03	1.14	.15	.08	6.15	99.21	.100	------
			b 69.72	.66	6.06	16.26	.060	1.37	1.40	2.16	1.21	.16	.09	------	99.20	------	------
32398	4	36–44	a 70.08	.58	4.35	14.02	.100	1.61	1.57	2.53	1.37	.16	.04	3.91	100.26	.058	------
			b 72.92	.60	4.53	14.59	.104	1.67	1.57	2.63	1.43	.17	.04	------	100.25	------	------
32399	5	44–60	a 68.45	.59	4.35	14.02	.080	2.27	1.68	2.51	1.44	.17	.07	4.61	100.24	.031	0.78
			b 71.79	.62	4.56	14.70	.084	2.38	1.76	2.63	1.51	.18	.07	------	100.28	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
32395	1	0– 6	0.2	0.3	0.1	1.7	25.6	54.4	18.5	100.4
32396	2	6–15	.1	.2	.2	1.2	25.7	57.7	14.8	99.9
32397	3	15–36	.0	.1	.0	.4	13.1	54.4	32.2	100.2
32398	4	36–44	.0	.0	.0	.3	23.9	57.0	18.9	100.1
32399	5	44–60	.0	.1	.1	.4	18.1	59.0	22.2	99.9

[1] Collected by T. D. Rice. [2] Analyzed by G. J. Hough. [3] Analyzed by J. B. Spencer.

The profile was not sampled in such a way as to show whether the carbonate, beginning at a depth of 44 inches, is accumulated carbonate or parent-rock carbonate. The percentage of carbonate to a depth of 60 inches is low. The claypan begins at a depth of 15 inches and extends to 36 inches, below which the material is heavier than that above the claypan but less heavy than the claypan. The claypan contains an apparent accumulation of iron oxide as well as of alumina but does not include an accumulation of alkalies and alkaline earths as a whole or of any one of them. This sample can not be considered as an illustration of claypan soils in extreme development.

According to the mechanical analysis, the percentage of clay in the claypan is considerably higher, in proportion to that in the material either above or below it, than is that of alumina or of sesquioxides in proportion to the percentages of the same substances above and below them. The percentage of clay in the claypan is more than twice that in the overlying layer and nearly 80 per cent more than that in the immediately underlying layer.

The several ratios, molecular equivalents, and silica with sesquioxides calculated are shown in Table 172.

TABLE 172.—*Sample of Crete silt loam, 3 miles west of Fairmont, Fillmore County, Nebr.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
32395	0– 6	11.17	57.41	--------	83.45	3.85	12.69	77.38	3.57	11.77
32396	6–15	10.72	54.62	--------	82.83	4.09	13.13	77.09	3.74	12.22
32397	15–36	7.29	30.48	--------	75.75	6.58	17.66	70.29	6.11	16.39
32398	36–44	8.49	42.66	--------	79.22	4.92	14.76	73.86	4.59	14.77
32399	44–60	8.30	41.72	--------	78.84	5.01	16.14	73.36	4.66	15.02

In this profile, material was not collected from beneath the carbonate zone, and the development of that zone is slight. The low ratios in layer 3 (15 to 36 inches), as well as the low percentages of silica when silica and sesquioxides are calculated to 100 and to a constant percentage of CaO and MgO, are very marked. The low sa ratios could be caused either by a low percentage of silica or a high percentage of alumina. In this case the recalculated percentages in the last two sections of the table show somewhat higher silica in the carbonate zone than in layer 3 yet not so

much as in layers 1 and 2. The percentages in layers 3, 4, and 5 are nearer alike than are those in layers 1 or 2 and 3. If silica has been removed from layer 3 to an extent sufficient to account entirely for the low ratio and its low percentage there should be a percentage in the carbonate zone higher than that present in either of the last two sections of the table and it should stand equal to or higher than that in layers 1 and 2. Since this is not the case, it is clear from the chemical data alone that the low ratios and the low percentages of silica in layer 3 are due, at least mainly, to the concentration of alumina, and the high percentages of silica in layers 1 and 2 are due to the removal of alumina from these layers. The alumina has concentrated in and below layer 3.

The very slight acidity of layers 1 and 2 indicate that this apparent eluviation is not the result of podzolization mainly, though it may have been a small contributing factor, but the physical character of layer 3 suggests that it is a layer of concentration due to the presence of carbonate of soda. It is apparently an incipient Solonetz, though no base-exchange studies have yet confirmed this interpretation.

A Crete silt loam profile from a point on the Chicago, Burlington & Quincy Railroad, 20 miles west of Lincoln, Nebr., has attained a more advanced stage of development of the layer of apparent alumina concentration than has that from Fairmont, Nebr. The composition of this material is shown in Table 173.

TABLE 173.—*Composition of Crete silt loam, Lincoln, Nebr.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34756	1	0- 6	[a] 73.96	1.66	2.42	9.61	0.04	0.82	0.33	1.76	1.10	0.22	0.14	7.94	100.00	0.150	------
			[b] 80.36	1.80	2.63	10.44	.04	.89	.36	1.91	1.19	.24	.15	------	100.01	------	------
34757	2	6-13	[a] 73.81	1.44	2.50	10.54	.05	.81	.37	1.82	.80	.24	.14	7.48	100.00	.150	------
			[b] 79.76	1.56	2.70	11.39	.05	.88	.40	1.97	.86	.26	.15	------	99.98	------	------
34758	3	13-15	[a] 74.51	1.66	2.74	10.72	.04	.77	.44	1.32	.74	.13	.07	6.86	100.00	.120	------
			[b] 79.99	1.78	2.94	11.51	.04	.83	.47	1.42	.79	.14	.08	------	99.99	------	------
34759	4	15-32	[a] 60.86	1.80	3.63	22.85	.04	.96	.71	1.74	.88	.31	.09	6.13	100.00	.120	------
			[b] 64.83	1.92	3.87	24.34	.04	1.02	.76	1.85	.94	.33	.10	------	100.00	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34756	1	0- 6	0.0	0.0	0.0	0.6	23.1	61.9	14.3	99.9
34757	2	6-13	0	0	0	.4	22.2	64.1	13.5	100.2
34758	3	13-15	0	0	0	.2	20.8	64.2	15.2	100.4
34759	4	15-32	0	0	0	.4	17.8	49.5	32.4	100.1
34760	5	32-40	0	0	0	.2	22.1	54.6	23.3	100.2

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Feb. 15, 1918.
[3] Analyzed by V. Jacquot.

It will be noted that the deepest layer included in the chemical composition table lies between 15 and 32 inches, or in the carbonate zone, whereas mechanical composition of material from an underlying layer is shown in the mechanical analysis table. The percentage of clay in the layer extending from 15 to 32 inches is 32, more than twice as much as that in the overlying layers, and that in the underlying layer is 9 per cent lower. The percentage of alumina in this zone of clay concentration is more than twice that in either of the overlying layers.

The percentage of organic matter is not high, but the soil is impregnated with considerable organic matter to a great depth, the percentage in the zone of clay concentration being but little less than in the surface soil. The percentages of alkalies and alkaline earths are so uniform throughout the profile that there seems to be no reason for computing the percentages of silica and sesquioxides either to a total of 100 or to a constant percentage of CaO and of MgO.

It has already been stated (p. 80) that central Washington and the northeastern part of Oregon with adjacent parts of Idaho constitute a miniature Great Plains region. From the point of view of its soils it is more complete than the Great Plains proper, since it includes the whole range of Pedocals from Chernozems to the Gray Desert soils. Only one profile of the Chernozem soils of the region has been studied in both the field and laboratory. It was not properly sampled, since no material was collected from either the carbonate zone or the parent material. The chemical composition of material from the upper horizons is shown in Table 174. No comparisons with the parent material can be made, but the uniform composition of the several layers to a depth of 35 inches shows that eluviation has not taken place. This soil is less eluviated than the Amarillo soils, probably because it is less sandy.

TABLE 174.—*Chemical composition of Palouse silt loam, North Pine, Wash.*[1] [2]

Sample No.	Horizon	Depth	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P.ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34705	1	0 -10	[a] 64.15	0.83	5.40	16.52	0.08	1.62	1.10	1.92	1.38	0.32	Trace.	6.68	100.00	0.190	------
			[b] 68.74	.89	5.79	17.70	.08	1.74	1.18	2.06	1.48	.34	do	------	100.00	------	------
34706	2	10 -23½	[a] 64.21	.83	6.05	16.62	.08	1.54	.99	2.14	1.62	.29	do	5.63	100.00	.140	------
			[b] 68.04	.88	6.41	17.61	.08	1.63	1.05	2.27	1.72	.31	do	------	100.00	------	------
34707	3	23½-35	[a] 64.18	.83	5.57	17.39	.08	1.44	1.32	2.06	1.84	.30	do	4.99	100.00	.080	------
			[b] 67.55	.87	5.86	18.30	.08	1.51	1.39	2.17	1.94	.31	do	------	99.98	------	------

[1] Collected by C. F. Marbut. [2] Analyzed in the division of soil chemistry, Bureau of Soils, Mar. 15, 1918.

COMPOSITION OF THE DARK-BROWN AND BROWN SOILS

The chemical composition of the Dark-Brown (Chestnut-Brown), Brown, and Gray soils of the Pedocal group has been determined for a number of profiles. In most cases samples were not collected below the zone of carbonate accumulation.

The Dark-Brown and Brown soils occur on the Great Plains, east of the Rocky Mountains, and in small areas on high plateaus and on mountain slopes within the various mountains of the West and in the Great Basin, as well as in narrow belts in the central parts of the States of Washington and Oregon. Definite boundary lines, either geographic or pedologic, between the various members of the Pedocals east of the Rocky Mountains have been approximately located only. They are all grassland soils, and those on the Great Plains become progressively lighter in color from east to west.

In the following brief discussion of their composition the Dark-Brown and Brown soils will not be differentiated except in a general way, but the members of the darker groups will be mentioned first. It will be noted that no attempt is made to designate horizons by the letters A, B, and C, the several layers, each differing from those adjacent to it, both above and below, being designated by number, beginning with the surface layer, order, or depth.

The Mandan (N. Dak.) experiment station lies in the eastern part of the belt of Dark-Brown soils. The chemical and mechanical composition of material from a profile on the upland of the station farm are shown in Table 175.

TABLE 175.—*Composition of Dark-Brown silt loam, Mandan, N. Dak.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28703	1	0- 7	[a] 70.31	0.57	3.47	12.47	0.087	1.12	0.76	2.52	1.05	0.17	0.11	7.64	100.28	0.244	------
			[b] 76.10	.62	3.75	13.50	.094	1.21	.82	2.73	1.14	.18	.12	------	100.27	------	------
28704	2	7-24	[a] 70.74	.66	4.03	13.18	.079	1.08	1.53	2.34	1.10	.17	.09	4.89	99.89	.110	------
			[b] 74.40	.69	4.24	13.86	.083	1.14	1.61	2.46	1.16	.18	.09	------	99.91	------	------
28705	3	24+	[a] 60.71	.55	3.91	12.97	.055	6.69	2.69	2.28	.91	.17	.09	9.16	100.19	.065	5.65
			[b] 66.85	.61	4.30	14.28	.061	7.36	2.96	2.51	1.00	.19	.10	------	100.22	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28703	1	0- 7	0.5	0.9	0.8	8.4	24.2	54.9	10.3	100.0
28704	2	7-24	.4	.4	.6	10.0	38.0	43.0	8.0	100.4
28705	3	24+	.2	.7	.8	16.0	25.2	42.4	14.7	100 0

[1] Collected by C. F. Marbut. [2] Analyzed by G. Edgington. [3] Analyzed by J. B. Spencer.

The percentage of organic matter (nitrogen) is high for the Dark-Brown soils, being higher than in the soils of the Chernozem belt south of South Dakota, and the dark-colored layer is thick. Carbonate accumulation is well defined, but the percentage of alumina is higher in the carbonate layer than above it. That of silica is lower.

The sa and sf ratios as well as the percentages of SiO_2 and of each of the principal sesquioxides calculated to a total of 100 and to a constant percentage of CaO (1.00) and of MgO (0.80) are shown in the several parts of Table 176.

TABLE 176.—*Sample of a Dark-Brown soil, Mandan, N. Dak.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO (1.00) and MgO (0.80)		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
28703	0- 7	8.95	53.77	----------	81.52	4.02	14.46	76.27	3.76	13.53
28704	7-24	9.20	46.50	----------	80.43	4.58	14.98	75.11	4.28	13.99
28705	24+	7.96	41.20	----------	78.25	5.03	16.71	72.55	4.66	15.49

The percentage of clay in the surface soil includes finely divided organic matter. The mechanical analysis of this sample was not made after removal of organic matter. The low percentage of clay in the second layer seems to be owing to the occurrence of a high percentage of very fine sand. It is geological, apparently, rather than pedological.

These results seem to be consistent in showing that no shifting of silica from layer 2 to the carbonate zone can have taken place. If any shifting of silica has taken place at all it has been away from the carbonate zone rather than to it. The higher percentage of sesquioxides in the carbonate zone is responsible for the low percentage of silica in the same zone, but in a soil where podzolization has not taken place the higher percentage of sesquioxides does not seem to be the result of shifting from overlying layers. The marked differences in all the constituents shown in the last two sections of the table seem to be due to parent material differences or to ground water. No information regarding the latter is available, and the probability of its presence is not great although the sample was taken on a rather large area of smooth relief. It is more probable that the differences are caused by parent material differences.

The chemical and mechanical composition of material from a profile of a Dark-Brown fine sandy loam from Williston, N. Dak., are shown in Table 177.

TABLE 177.—*Composition of Dark-Brown fine sandy loam, Williston, Williams County, N. Dak.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P ct.*	*P ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28694	1	0-1½	[a] 74.15	0.63	2.78	11.35	0.060	1.33	0.80	2.25	1.22	0.16	0.09	6.06	100.88	0.210	0.12
			[b] 78.92	.67	2.96	12.07	.060	1.42	.85	2.39	1.30	.17	.10	------	100.91	------	------
28695	2	1½- 7	[a] 74.05	.55	3.47	11.59	.067	1.17	.92	2.26	1.35	.11	.14	4.85	100.53	.150	------
			[b] 77.80	.58	3.65	12.17	.070	1.23	.97	2.38	1.42	.12	.15	------	100.54	------	------
28696	3	7-12	[a] 74.23	.56	3.35	12.05	.074	1.20	1.11	2.18	1.25	.09	.11	3.96	100.16	.090	------
			[b] 77.30	.58	3.49	12.54	.077	1.25	1.16	2.27	1.30	.09	.11	------	100.17	------	------
28697	4	12-30	[a] 64.53	.52	3.47	12.21	.093	5.79	2.00	2.33	.91	.16	.06	8.21	100.28	.077	4.73
			[b] 70.28	.57	3.78	13.30	.101	6.31	2.18	2.54	.99	.17	.07	------	100.29	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28694	1	0-1½	0.2	1.9	2.6	20.2	26.0	42.0	7.0	99.9
28695	2	1½- 7	.0	1.4	2.8	21.0	28.3	38.7	7.3	99.5
28696	3	7-12	.1	1.1	2.5	24.0	26.5	37.4	8.3	100.0
28697	4	12-30	.1	.4	.7	11.9	24.9	47.5	15.1	100.6

[1] Collected by C. F. Marbut. [2] Analyzed by G. Edgington. [3] Analyzed by J. B. Spencer.

This profile is less dark than the profile at Mandan. The soil lies farther west than the latter and in a region where precipitation is somewhat lower. It contains a

higher percentage of Al_2O_3, and this is a factor in determining the color. The thickness of the dark-colored layer is less, and the depth to the carbonate accumulation zone is less. The carbonate zone is well developed, and field evidence shows it to be a zone of accumulation though the composition of the parent material is not shown in the analysis tables.

The sa and sf ratios and the composition of silica and of the principal sesquioxides calculated to a total of 100 and to a constant percentage of CaO and MgO are shown in Table 178.

TABLE 178.—*Sample of a Dark-Brown fine sandy loam, Williston, N. Dak.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
28694	0 – 1½	11.11	70.65	----	84.00	3.15	12.85	79.05	2.96	12.09
28695	1½– 7	10.86	56.47	----	83.10	3.90	14.06	77.87	3.65	12.17
28696	7 –12	10.48	58.70	----	82.82	4.22	13.43	77.53	3.50	12.57
28697	12 –30	8.98	49.27	----	80.76	4.32	15.22	74.77	4.02	14.14

As in the Mandan profile the percentage of silica in the carbonate zone is low and that of each of the sesquioxides is high. The percentage of increase of Fe_2O_3 over that in layer 3 is about 15, and that of alumina is about 12.5. An increase of silica in the carbonate zone would cause the percentages of the sesquioxides to decrease. It is evident that no accumulation of silica has taken place in the carbonate zone, but both iron oxide and alumina have accumulated.

The chemical and mechanical composition of material from a profile of a Dark-Brown soil (Rosebud silt loam) near Dalton, Nebr., are shown in Table 179.

TABLE 179.—*Composition of Rosebud silt loam, Dalton, Nebr.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28744	1	0– 4	[a]70.98	0.62	3.58	12.20	0.62	1.74	1.15	2.81	1.53	0.12	0.02	6.07	101.44	0.10	------
			[b]75.52	.66	3.81	12.97	.66	1.85	1.23	2.99	1.63	.13	.02	------	101.47	------	------
28745	2	5–14	[a]70.70	.64	3.80	13.51	.59	1.75	1.17	2.82	1.46	.11	.02	3.65	100.22	.06	------
			[b]73.36	.66	3.94	14.02	.61	1.82	1.21	2.93	1.51	.11	.02	------	100.19	------	------
28746	3	14–38	[a]66.27	.60	3.80	13.38	.04	4.42	1.60	3.07	1.55	.13	.20	5.60	100.66	.05	------
			[b]70.20	.64	4.02	14.18	.04	4.68	1.69	3.25	1.64	.14	.21	------	100.69	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28744	1	0– 4	0.2	1.2	1.1	8.4	49.0	34.7	5.6	100.3
28745	2	5–14	.6	.9	.8	6.2	47.9	32.5	11.2	100.1
28746	3	14–38	.2	.7	.4	3.9	50.2	33.5	11.3	100.2

[1] Collected by C. F. Marbut. [2] Analyzed by W. O. Robinson and G. J. Hough. [3] Analyzed by J. B. Spencer.

This soil has been given recognition in the detailed work of the Soil Survey as a soil series under the name of Rosebud. It occurs over a wide area in western Nebraska and adjoining States. Material from the C horizon was not collected, the lowest layer sampled being the carbonate layer. The percentage of organic matter is lower than in the samples from Mandan and Williston, N. Dak. The carbonate accumulation is definite but not high.

The sa and sf ratios and the percentages of silica and of each of the sesquioxides recalculated to a total of 100 and to constant percentages of CaO and of MgO are shown in Table 180.

TABLE 180.—*Sample of Rosebud silt loam, Dalton, Nebr.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
28744	0– 4	9.9	52.54	----	81.82	4.13	14.05	75.58	3.81	12.98
28745	5–14	8.89	49.34	----	80.33	4.31	15.35	73.38	3.91	14.03
28746	14–38	8.416	46.27	----	79.41	4.54	16.04	72.56	4.15	14.68

The same relationship of silica and sesquioxides to the carbonate-accumulation zone and that overlying it are shown as exist in the Mandan and Williston localities, but the differences are much less. Slight accumulation of sesquioxides has taken place in the carbonate zone with no accumulation of silica, or if there is any at all it is much less than that of alumina. Theoretically the trend should be reversed, an accumulation of silica should take place without change of alumina, unless, under the circumstances, the solubility of silica be so much greater than that of the carbonates of calcium and magnesium that the silica is carried into the immediately underlying layer. The number of profiles in which material from deeper layers has been analyzed does not seem to be sufficient to determine whether this be the case or not.

The Rosebud soils cover, according to the soil map in this publication (pl. 5, secs. 3 and 6), a large area of the Great Plains. It has already been stated that although the soils of all this area are similar and in general characteristics are like the Rosebud soils, the true Rosebud soils occur only in western Nebraska and adjoining parts of States bordering Nebraska. The experiment station farm at Ardmore, S. Dak., is on Rosebud soils. The composition of material from a profile on the station farm is shown in Table 181.

TABLE 181.—*Composition of Rosebud silt loam, Ardmore, Fall River County, S. Dak.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28741	1	0– 2	[a]70.05	1.08	4.34	11.19	0.07	1.20	1.03	2.58	1.38	0.19	0.74	7.09	100.94	0.190	------
			[b]75.37	1.16	4.67	12.03	.08	1.29	1.11	2.78	1.48	.20	.80	------	100.97	------	------
28742	2	2–13	[a]62.62	1.15	6.20	15.07	.05	1.45	1.63	2.51	1.03	.12	1.17	7.75	100.75	.180	------
			[b]67.86	1.25	6.72	16.32	.05	1.57	1.77	2.72	1.12	.13	1.27	------	100.78	------	------
28743	3	13–36	[a]57.94	1.07	5.19	12.62	.06	7.65	1.58	2.17	1.07	.23	1.06	9.99	100.63	.110	4.83
			[b]64.35	1.19	5.76	14.02	.07	8.48	1.75	2.41	1.19	.26	1.18	------	100.66	------	------

[1] Collected by C. F. Marbut. [2] Analyzed by F. A. Barker.

TABLE 181.—*Composition of Rosebud silt loam, Ardmore, Fall River County, S. Dak.*—Continued

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28741	1	0– 2	------	------	------	------	------	------	------	------
28742	2	2–13	6.9	10.3	6.6	7.5	6.0	16.8	43.8	97.9
28743	3	13–36	13.3	15.8	10.0	10.2	6.8	10.9	31.7	98.7

[3] Analyzed by L. T. Alexander.

The slight depth to the carbonate zone shows that the soil occurs in a region of low rainfall, but the percentage of nitrogen is high. The cover of grass is good. This area is within one of the soil belts surrounding the Black Hills, where the climate is cool and showers are somewhat more frequent than on the more exposed plains, although the total precipitation is low. Material from the C horizon was not analyzed.

The sa and sf ratios and the percentages of SiO_2, Fe_2O_3, and Al_2O_3 when calculated to a total of 100 and also to constant percentages of CaO (1.25) and MgO (1.00) are shown in the several parts of Table 182.

TABLE 182.—*Sample of Rosebud silt loam, Ardmore, Fall River County, S. Dak.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO (1.25) and MgO (1.00)		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
28741	0– 2	10.650	42.77	----	81.86	5.07	13.06	75.45	4.68	12.05
28742	2–13	7.068	26.76	----	74.65	7.39	17.95	68.60	6.79	16.50
28743	13–36	7.803	29.60	----	76.49	6.84	16.66	69.48	6.22	15.14

The composition shows apparent concentration of both alumina and iron oxide in layer 2, a characteristic not present in most of the Pedocals shown on preceding pages. Such a relationship could be brought about by accumulation of silica alone, without change of actual amount of other constituents, in layer 3. The morphology of the profile shows that layer 2 is a layer of heavy rather plastic clay. This is a Rosebud soil in which Solonetz development has taken place to a slight extent. Where such development has reached a more advanced stage, but where in other respects the features of the Rosebud series are dominant, the soils have been given recognition as independent soils in the Dawes series.

The composition of material from a profile of Dawes silt loam in the Goshen Hole region of Wyoming is shown in Table 183.

TABLE 183.—*Composition of Dawes silt loam, Goshen Hole, Wyo.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
34700–1	1	0–12	[a]70.20	0.53	3.38	12.16	0.030	2.86	1.56	2.52	1.22	0.24	0.02	5.25	100.00	0.100	------
			[b]74.08	.56	3.58	12.83	.060	3.02	1.65	2.66	1.29	.25	.02	------	100.00	------	------
34702	2	12–22½	[a]69.26	.50	3.52	13.75	.006	2.26	1.93	2.54	1.04	.20	.06	4.93	100.00	.100	------
			[b]72.87	.53	3.70	14.46	.006	2.38	2.03	2.67	1.09	.21	.06	------	100.01	------	------
34703	3	22½–33	[a]62.36	.46	2.82	13.68	.060	7.44	1.90	2.40	1.06	.22	.10	7.50	100.00	.060	------
			[b]67.41	.50	3.05	14.78	.060	8.04	2.05	2.59	1.15	.24	.11	------	99.98	------	------
34704	4	33–36	[a]62.86	.48	2.11	11.73	.040	8.14	1.95	2.41	1.14	.33	.03	8.78	100.00	.030	------
			[b]68.90	.53	2.31	12.86	.040	8.92	2.14	2.64	1.25	.36	.03	------	99.98	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
34700–1	1	0 –12	0.1	0.2	4.5	2.6	32.5	39.5	20.6	100.0
34702	2	12 –22½	0	.1	.5	3.4	32.9	35.8	27.2	99.9
34703	3	22½–33	0	.1	.2	1.4	22.8	43.7	31.8	100.0
34704	4	33 –36	0	.0	.1	.6	17.5	59.4	22.4	100.0

[1] Collected by J. O. Veatch.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Feb. 15, 1918.
[3] Analyzed by H. W. Lakin.

The percentages of clay in layers 3 and 4 are higher than those in the layers above or below. That of alumina is higher also, but not so high in proportion to the other layers as is the clay percentage. Iron oxide percentage in 4 is lower than in 1 and 2, and in 3 is not significantly higher. The apparent accumulation in 3 and 4, therefore, concerns alumina alone rather than both the principal sesquioxides. There is an apparent well-defined accumulation of alumina above and in the upper part of the carbonate zone.

The sa and sf ratios and the percentages of SiO_2, Fe_2O_3, and Al_2O_3 calculated to a total of 100 and to constant percentages of CaO and MgO are shown in Table 184.

TABLE 184.—*Sample of Dawes silt loam, Goshen Hole, Wyo.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
34700–1	0 –12	9.80	54.83	----	81.86	3.95	14.18	74.76	3.61	12.94
34702	12 –22½	8.57	52.19	----	79.93	4.06	15.88	73.35	3.72	14.55
34703	22½–33	7.75	58.57	----	79.08	3.58	17.34	71.68	3.24	15.72
34704	33 –36	9.11	79.00	----	81.95	2.75	15.29	73.93	2.48	13.80

The same accumulation of alumina and iron oxide in the layers immediately above the carbonate zone and below the surface layer has taken place here as in the Ardmore profile, but the concentration is greater, the content of alumina in layer 3 is nearly 17 per cent higher than that in the carbonate layer, and that of iron oxide is nearly 30 per cent higher. The surface soil to a depth of 12 inches has a lower percentage of alumina than any of the other layers, but the content of iron oxide is higher than that in the carbonate zone or the layer immediately above it.

The composition of material from a profile of a Dark-Brown soil, about the equivalent of the Rosebud, from the Agricultural Experiment Station farm at Dickinson, N. Dak., is shown in Table 185.

TABLE 185.—*Composition of a Dark-Brown fine sandy loam, Dickinson, N. Dak.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28711	1	0– 7	[a]68.00 [b]74.34	0.62 .68	3.93 4.30	11.50 12.58	0.05 .05	1.25 1.37	1.13 1.23	2.43 2.65	1.60 1.75	0.19 .21	0.30 .33	8.52 ------	99.52 99.49	0.290 ------	------ ------
28712	2	7–14	[a]68.00 [b]72.38	.68 .72	5.57 5.93	13.59 14.46	.05 .05	1.23 1.31	1.69 1.80	2.45 2.61	1.33 1.42	.16 .17	.31 .33	6.05 ------	101.11 101.14	.120 ------	------ ------
28713	3	14–40	[a]64.60 [b]69.58	.76 .82	4.92 5.30	13.50 14.53	.04 .04	3.49 3.76	2.24 2.41	2.24 2.41	1.32 1.42	.16 .17	.36 .39	7.17 ------	100.80 100.83	.070 ------	1.74 ------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28711	1	0– 7	0.2	1.7	3.0	28.1	24.8	28.5	13.7	100.0
28712	2	7–14	.4	1.2	2.3	20.7	24.0	36.2	15.2	100.0
28713	3	14–40	.0	2.0	9.1	26.6	21.6	26.3	19.4	100.0

[1] Collected by C. F. Marbut. [2] Analyzed by G. J. Hough. [3] Analyzed by J. B. Spencer.

The texture is fine sandy loam. The top of the zone of carbonate accumulation lies at a depth of 14 inches, which seems to be a little less than the average depth in the Rosebud soils, but the percentage of organic matter is higher than usual. The thickness of the dark-colored layer is fully equal to that of the Rosebud soils in general but a little less than in the Dalton, Nebr., profile. The complete analysis gives no suggestion of the presence in any layer of sesquioxide accumulation similar to that in the Goshen Hole, Wyo., and Ardmore, S. Dak., profiles. Parent-rock material below the zone of carbonate accumulation was not obtained.

The sa and sf ratios and the percentages of silica and each of the important sesquioxides calculated to 100 and to constant percentages of CaO and MgO are shown in Table 186.

TABLE 186.—*Sample of a Dark-Brown fine sandy loam, Dickinson, N. Dak.*

Sample No.	Depth in inches	Ratios: sa	sf	ba	Percentage calculated to a total of 100: SiO₂	Fe₂O₃	Al₂O₃	Percentage calculated to constant percentages of CaO and MgO: SiO₂	Fe₂O₃	Al₂O₃
28711	0– 7	10.04	45.81	------	81.49	4.71	13.79	74.41	4.30	12.59
28712	7–14	8.51	32.34	------	77.91	6.39	15.58	72.82	5.97	14.55
28713	14–40	8.14	34.79	------	77.82	5.92	16.25	72.13	5.49	15.06

The close similarity of layers 2 and 3 as measured by the ratios and by the percentages in both computations is very striking. In none of the other soils of the Dark-Brown group have the layers below the thin surface layer been so nearly alike. It is evident that practically no shifting of silica or of the sesquioxides has taken place. The high percentage of silica and low percentages of the sesquioxides in the surface soil as compared with the other layers shows the same characteristic as is present in greater or less development in all the Pedocals. It has already been briefly discussed on page 86.

A Dark-Brown soil from near Gillette, Wyo., the composition of which is shown in Table 187, seems to have attained about the same stage of development as that at Dickinson and to have been influenced as little by the presence of salts or of any other factor tending to interfere with normal development as the soil at Dickinson. The percentage of clay in layer 2 is a little higher than in layer 1, but the difference is small. The low percentage in layer 3 is due to the presence of carbonate of calcium.

TABLE 187.—*Composition of a Dark-Brown sandy clay, Gillette, Wyo.*[1]

Sample No.	Horizon	Depth	Chemical[2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28588	1	0–2	[a]76.19 [b]80.01	0.54 .57	3.00 3.15	10.00 10.50	0.034 .036	0.65 .68	0.91 .96	2.72 2.86	0.85 .89	0.11 .12	0.21 .22	4.79 ------	100.00 100.00	0.160 ------	Tr. ------
28589	2	2–9	[a]70.25 [b]75.19	.62 .66	3.47 3.71	13.20 14.13	.040 .040	.99 1.06	1.11 1.19	2.54 2.72	.87 .93	.13 .14	.24 .26	6.54 ------	100.00 100.00	.110 ------	0.00 ------
28590	3	9+	[a]65.59 [b]71.11	.57 .62	3.97 4.31	12.34 13.38	.045 .049	4.37 4.74	1.26 1.37	2.18 2.36	1.54 1.67	.14 .15	.19 .21	7.80 ------	100.00 99.97	.060 ------	2.93 ------

Sample No.	Horizon	Depth	Mechanical[3] Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28588	1	0–2	0.2	1.5	1.0	20.1	27.7	17.9	21.4	99.9
28589	2	2–9	.7	.8	.9	22.4	22.8	27.6	24.4	99.6
28590	3	9+	.1	.3	.8	23.1	29.4	31.8	14.4	99.9

[1] Collected by C. F. Marbut. [2] Analyzed by R. S. Holmes. [3] Analyzed by J. B. Spencer.

The sa and sf ratios and the percentages of silica and each of the sesquioxides calculated as in preceding cases are shown in Table 188.

TABLE 188.—*Sample of a Dark-Brown soil, 20 miles south of Gillette, Wyo.*

Sample No.	Depth in inches	Ratios: sa	sf	ba	Percentage calculated to a total of 100: SiO₂	Fe₂O₃	Al₂O₃	Percentage calculated to constant percentages of CaO and MgO: SiO₂	Fe₂O₃	Al₂O₃
28588	0–2	12.950	67.31	------	85.42	3.36	11.21	80.20	3.16	10.52
28589	2–9	9.046	53.70	------	80.82	3.99	15.19	75.83	3.74	14.25
28590	9+	9.035	43.72	------	80.08	4.85	15.07	74.45	4.51	14.01

A slight shifting of iron oxide into the carbonate zone seems to have taken place, accounting for the lower sf ratio for that layer.

No shifting of alumina has taken place, and the apparent shifting of silica is most easily accounted for by the result of the increased percentage of iron oxide in the carbonate zone.

The chemical composition of material from a profile of Dark-Brown soil at Colby, Kans., which may be considered as a silty member of the Rosebud group, is shown in Table 189.

TABLE 189.—*Chemical composition of a Dark-Brown soil, Colby, Kans.*[1 2]

Sample No.	Horizon	Depth	SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28028	1	0– 1½	[a]72.91 [b]76.24	0.53 .55	3.31 3.46	11.52 12.04	0.05 .06	1.73 1.81	1.16 1.21	2.23 2.33	1.27 1.33	0.15 .16	0.11 .11	4.35 ------	99.33 99.30	0.160 ------	------ ------
28029	2	4– 5	[a]70.14 [b]73.66	.52 .55	4.42 4.64	12.93 13.57	.05 .05	1.65 1.73	1.27 1.33	2.41 2.53	1.61 1.69	.13 .14	.15 .16	4.82 ------	100.01 100.05	.180 ------	------ ------
28030	3	5– 9	[a]60.69 [b]66.59	.49 .54	2.64 2.89	11.99 13.65	.05 .05	8.53 9.36	1.80 1.97	2.52 2.76	1.45 1.59	.16 .18	.12 .13	8.80 ------	99.24 99.21	.140 ------	------ ------
28031	4	9–40	[a]62.64 [b]67.47	.52 .56	3.28 3.53	11.68 12.58	.05 .05	7.79 8.39	1.87 2.01	2.57 2.77	1.47 1.58	.18 .19	.11 .12	7.12 ------	99.28 99.25	.100 ------	------ ------

[1] Collected by C. F. Marbut.
[2] Analyzed by W. B. Pope.

The sa and sf ratios and the percentages of silica and of each of the important sesquioxides, calculated as in the preceding cases, are shown in Table 190.

TABLE 190.—*Sample of a Dark-Brown soil, Colby, Kans.*

Sample No.	Depth in inches	Ratios: sa	sf	ba	Percentage calculated to a total of 100: SiO₂	Fe₂O₃	Al₂O₃	Percentage calculated to constant percentages of CaO and MgO: SiO₂	Fe₂O₃	Al₂O₃
28028	0– 1½	10.76	58.39	------	83.10	3.77	13.12	76.48	3.47	12.08
28029	4– 5	9.23	42.06	------	80.18	5.05	14.77	73.92	4.66	13.62
28030	5– 9	8.61	61.06	------	80.59	3.49	15.91	72.34	3.14	14.28
28031	9–40	9.12	50.65	------	80.72	4.22	15.05	72.67	3.80	13.55

The uniformity in the content of silica and each of the important sesquioxides in all the layers of the profile is striking. A slightly higher percentage of alumina in layer 3 with the usual higher silica and lower content of sesquioxides in the surface layer, in this sample a thin layer, is the only variation from practical uniformity. The difference between the content of silica in the surface layer and the lower layers is greater than usual, owing probably to the slight thickness of this layer.

The chemical composition of material from a Dark-Brown soil at Cheyenne Wells, Colo., within a few miles of the Kansas-Colorado boundary is shown in Table 191.

TABLE 191.—*Chemical composition of a Dark-Brown soil, Cheyenne Wells, Colo.*[1 2]

Sample No.	Horizon	Depth	SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28043	1	0– 2	[a]72.70 [b]75.13	0.450 .460	2.99 3.09	14.10 14.57	0.041 .042	1.33 1.37	0.66 .68	1.49 1.54	2.86 2.96	0.037 .038	0.173 .179	3.26 ------	100.09 100.09	0.074 ------	------ ------
28044	2	2– 8	[a]64.60 [b]68.67	.487 .518	4.07 4.33	16.90 17.97	.031 .033	1.36 1.45	1.17 1.24	2.59 2.75	3.36 3.57	.012 .013	.188 .200	5.94 ------	100.71 100.74	.146 ------	------ ------
28045	3	8–24	[a]57.80 [b]64.12	.343 .381	3.85 4.27	13.25 14.70	.036 .040	9.40 10.42	1.77 1.96	1.68 1.86	2.62 2.91	.018 .020	.124 .138	9.90 ------	100.79 100.82	.069 ------	------ ------
28046	4	24–40	[a]63.70 [b]68.18	.427 .457	3.35 3.58	14.30 15.29	.041 .044	6.16 6.58	1.55 1.66	2.20 2.35	2.30 2.46	.031 .033	.051 .055	6.55 ------	100.66 100.69	.017 ------	------ ------

[1] Collected by C. F. Marbut.
[2] Analyzed by G. J. Hough.

The soil in this locality has developed from local material, whereas that at Colby was developed on silty material, presumably loess. The Cheyenne Wells soil is heavier than that at Colby, and the profile was sampled below the carbonate zone.

The sa and sf ratios and the percentages of SiO_2, Fe_2O_3, and Al_2O_3 calculated to a total of 100 and also to constant percentages of CaO and MgO are shown in the several parts of Table 192.

TABLE 192.—*Sample of a Dark-Brown soil, Cheyenne Wells, Colo.*

Sample No.	Depth in inches	Ratios: sa	sf	ba	Percentage calculated to a total of 100: SiO₂	Fe₂O₃	Al₂O₃	Percentage calculated to constant percentages of CaO and MgO: SiO₂	Fe₂O₃	Al₂O₃
28043	0– 2	8.768	64.45	------	80.10	3.29	15.53	75.28	3.10	14.60
28044	2– 8	6.497	42.63	------	75.48	4.76	19.75	69.25	4.37	18.12
28045	8–24	7.413	39.81	------	77.17	5.14	17.69	70.87	4.72	16.24
28046	24–40	7.573	50.45	------	78.32	4.11	17.56	72.54	3.81	16.27

A slight accumulation of silica in the parent material, which may very well be due to the presence of a somewhat sandy stratum, and the concentration of alumina in layer 2 are the two respects in which this soil differs from the soil at Colby, Kans. Since the increase in content in layer 2 is confined to alumina, it is evident that the difference is not due to a leaching of silica from this layer. If that were the case the percentage of iron oxide would be greater.

COMPOSITION OF THE GRAY DESERT SOILS

The morphology of the Gray Desert soils has been described on page 81 of this publication. The chemical and mechanical composition of six samples from rather widely scattered points of the region east of the Sierra Nevada-Cascade Mountains and west of the Wasatch are shown in Tables 193, 195, 197, 199, 200, and 201.

In general these soils do not effervesce at the surface, but carbonates lie within a few inches below. The analyst actually determined the presence of CO_2 from carbonates in only a few of the soils, but field evidence and the high percentage of CaO in all of them leave no doubt of the presence of carbonate of calcium at slight depth. In the sample from Twin Falls, Idaho, the absence of carbonates above a depth of 14 inches was definitely established.

In every sample except that from Delta, Utah, the percentage of lime in the thin loose surface layer is lower than in the layer immediately beneath it. The sample from Delta, Utah, was taken from a locality where alkaline salts have been accumulating, due to irrigation, for half a century. If excess irrigation water has not flowed over the spot from which the sample was taken, wind has distributed sediment from overflow irrigation water widely over the area.

The loose surface horizon of these soils, with relatively low CaO, is similar in morphological and chemical features with the similar surface layer in the Dark-Brown and Brown soils.

The percentage of nitrogen is low, averaging less than 0.10 per cent in the horizons containing the organic matter. In this respect, in the presence of carbonates at or very near the surface and in details of profile character, these soils differ from the other Pedocal groups.

The composition of Portneuf silt loam is shown in Table 193.

TABLE 193.—*Composition of Portneuf silt loam, Twin Falls, Idaho* [1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
540901	1	0-3	[a]72.44	0.64	3.92	12.16	0.06	2.04	1.47	2.57	1.77	0.17	0.13	3.63	101.00	0.070	------
			[b]75.14	.66	4.07	12.62	.06	2.12	1.52	2.66	1.84	.18	.13	------	101.00	------	------
540902	2	4-14	[a]68.69	.65	4.30	12.91	.05	2.73	1.75	2.42	2.01	.20	.08	4.85	100.64	.080	------
			[b]72.19	.68	4.51	13.56	.05	2.87	1.84	2.54	2.11	.21	.08	------	100.65	------	------
540903	3	15-36	[a]58.06	.49	3.10	9.67	.05	10.80	3.41	1.98	1.80	.18	.20	11.30	101.04	.030	8.42
			[b]65.35	.55	3.49	10.89	.06	12.16	3.84	2.23	2.03	.20	.23	------	101.03	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
540901	1	0-3	0.0	0.0	0.7	2.3	32.6	54.6	9.8	100.0
540902	2	4-14	0	.4	.3	3.4	34.9	50.5	10.5	100.0
540903	3	15-36	0	2.1	1.3	3.6	29.6	55.0	8.4	100.0

[1] Collected by Mark Baldwin. [2] Analyzed by G. J. Hough. [3] Analyzed by A. A. Riley.

The mechanical composition table shows a slightly higher percentage of clay in the firm layer extending from 4 to 14 inches than in the thin loose surface layers. In the latter the percentage of sand of all classes is lower than in either of the other layers. That of silt is a little higher.

The percentage of nitrogen is 0.07 in the thin loose surface layer and 0.08 in the firm structureless layer beneath. In the brush-land soils in general the second layer, as in the Brown soils of the grasslands, is the seat of maximum plant-root accumulation. The low percentages of nitrogen bring out the difference in this respect between the brush-land and grassland soils. The percentages of alumina and iron oxide in the thin loose surface layer are both a little lower than in the second layer, but those in the third layer are lower than in either of the other layers. It is evident that most, if not all, of this is due to the high percentages of CaO and MgO.

The sa and sf ratios, the percentages of silica, iron oxide, and alumina calculated to a total of 100, and also to a constant percentage of CaO and MgO, are shown in the several parts of Table 194.

TABLE 194.—*Sample of Portneuf silt loam, Twin Falls, Idaho*

Sample No.	Depth in inches	Ratios: sa	sf	ba	Percentage calculated to a total of 100: SiO₂	Fe₂O₃	Al₂O₃	Percentage calculated to constant percentages of CaO and MgO: SiO₂	Fe₂O₃	Al₂O₃
540901	0-3	10.12	48.97	------	81.82	4.43	13.73	75.24	4.05	12.64
540902	4-14	9.05	42.64	------	80.44	5.04	14.56	73.06	4.56	13.72
540903	15-36	10.20	49.62	------	81.97	4.38	13.66	73.52	3.93	12.25

As in the Dark-Brown and Brown soils, the presence of slightly higher percentages of both iron oxide and alumina in the second, or firm, layer is shown in all the ratios and recalculated results. Since the iron-alumina ratios (not shown in the table) are slightly different in the several layers, it is clear that apparent accumulation in layer 2 is not due to a removal of silica but is, in part at least, due to shifting of sesquioxides, though the amount is very small. The field evidence confirms the analytical evidence in the matter, however.

In chemical profile features this profile seems to be in no feature fundamentally different from that of the Brown or Dark-Brown soils. Such differences as exist are differences of degree rather than of kind.

The composition of material from a profile of Mohave loam from Buckeye, Maricopa County, Ariz., is shown in Table 195.

TABLE 195.—*Composition of Mohave loam, Buckeye, Maricopa County, Ariz.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
510944	1	0-6	[a]67.44	0.60	5.31	14.40	0.100	2.04	1.52	2.72	1.73	0.22	0.10	3.35	99.53	0.030	0.20
			[b]69.78	.62	5.49	14.90	.100	2.11	1.57	2.82	1.79	.23	.10	------	99.52	------	------
510945	2	6-14	[a]68.27	.61	5.35	13.86	.086	2.51	1.53	2.59	1.86	.12	.11	3.47	100.36	.010	.56
			[b]70.69	.63	5.54	14.35	.089	2.60	1.58	2.68	1.93	.12	.18	------	100.39	------	------
510947	3	20-50	[a]51.15	.45	3.77	9.39	.040	16.07	1.60	1.80	.90	.17	.14	14.06	99.54	.006	11.10
			[b]59.54	.52	4.40	10.94	.050	18.70	1.86	2.09	1.05	.20	.16	------	99.51	------	------
510949	4	68-78	[a]70.70	.48	5.10	12.40	.056	2.98	1.09	2.18	1.92	.15	.13	2.38	99.56	.000	.71
			[b]72.44	.49	5.22	12.70	.057	3.05	1.12	2.24	1.97	.15	.13	------	99.57	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
510944	1	0-6	4.2	8.2	5.2	26.2	20.4	23.0	12.7	99.9
510945	2	6-14	3.1	7.1	3.9	21.0	28.3	21.6	15.1	100.1
510947	3	20-50	10.5	11.0	4.2	11.2	15.5	33.1	14.5	100.0
510949	4	68-78	11.9	23.4	13.1	25.3	12.1	11.4	2.8	100.0

[1] Collected by W. G. Harper and F. O. Youngs. [2] Analyzed by G. J. Hough. [3] Analyzed by V. Jacquot.

Like the Twin Falls, Idaho, profile the surface layer contains a very low percentage of organic matter. Carbonates are present in small amounts from the surface downward. This is a characteristic of the Gray soils of a considerable part of the area in which they occur, but is not universal, as the Twin Falls profile shows. It is apparent that the latter profile is more typical of a normally developed Gray soil than those with carbonates in the surface layer. The Twin Falls profile lies in a region where recent accumulation of material by sedimentation has not taken place.

The soils of the greater part of the region, however, lie in situations where sedimentation may take place frequently. This is because of their situation on alluvial fan slopes, all of which are graded slopes but on which the intermittent streams building them may wander widely and deposit fresh material. Although the slopes are graded, they are still in process of gradation. The freshly deposited material is apt to be calcareous. While it is true that knowledge of Gray soils is very limited, it seems that their normal development removes the carbonates from the surface soil by the time maturity is reached.

The sa and sf ratios and the percentages of SiO_2 and of each of the principal sesquioxides when calculated to a total of 100 and also to constant percentages of CaO and MgO are shown in Table 196.

TABLE 196.—*Sample of Mohave loam, Buckeye, Maricopa County, Ariz.*

Sample No.	Depth in inches	Ratios: sa	sf	ba	Percentage calculated to a total of 100: SiO₂	Fe₂O₃	Al₂O₃	Percentage calculated to constant percentages of CaO and MgO: SiO₂	Fe₂O₃	Al₂O₃
510944	0-6	7.92	33.68	------	76.87	6.22	16.89	70.25	5.52	15.00
510945	6-14	8.37	33.81	------	78.04	6.11	14.35	71.52	5.60	14.52
510947	20-50	9.25	35.86	------	79.38	5.87	14.61	70.00	5.17	12.64
510949	68-78	9.70	36.77	------	80.16	5.77	14.05	74.01	5.38	12.98

These results show very strikingly that the Mohave profile in relative content of alumina in the several horizons is not identical with the profiles of the Portneuf soil or of the Dark-Brown and Brown grassland soils. The surface layer has a higher percentage of alumina than the one immediately underlying it. The sa and sf factors are very much alike for the carbonate layer and the layer beneath. The thickness of the surface layer will not account for the higher percentage of alumina on the supposition that it includes what corresponds to the loose surface layer and the firm layer in the Portneuf and other profiles, since the layer extending from 6 to 14 inches lies above the carbonate-accumulation zone and corresponds therefore to the firm layer. The explanation of the unusual profile seems to lie in the topographic position of the Mohave soils and in the processes by which their material has been accumulated. They have developed from alluvial-fan material and on fans that are likely to be subjected at any time to the influence of sedimentation and shifting of material. They are well graded but are still in process of upbuilding. It is probable that the surface material of this Mohave profile, to a depth of several inches, has recently been shifted by flooding. The zone of carbonate accumulation is well defined, showing that the deeper layers of the profile have long been in place, but the surface layers seem to have been shifted recently.

The mechanical composition of the whole soil, Table 195, shows that although the percentage of alumina is higher in the surface layer than in the second layer the percentage of clay is lower but that of silt higher. This tends to confirm the explanation just given. The material deposited on these slopes by flood waters either from the hills or from escaping irrigation is predominantly silty, the clay being carried still farther.

The composition of material from a profile of Gray soil located 12 miles south of Ely, Nev., is shown in Table 197.

TABLE 197.—*Composition of Gray soil, Ely, Nev.*[1]

Sample No.	Horizon	Depth	Chemical [2] SiO₂	TiO₂	Fe₂O₃	Al₂O₃	MnO	CaO	MgO	K₂O	Na₂O	P₂O₅	SO₃	Ignition loss	Total	N	CO₂ from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
29343	1	0-1½	[a]64.37	0.50	3.84	13.89	0.155	3.82	2.64	3.10	1.64	0.24	0.12	6.08	100.40	0.106	1.65
			[b]68.52	.53	4.09	14.78	.165	4.06	2.81	3.30	1.75	.26	.13	------	100.40	------	------
29344	2	1½-4	[a]61.69	.47	3.87	13.77	.118	5.48	2.60	2.90	1.47	.18	.12	7.62	100.29	.097	3.00
			[b]66.77	.51	4.19	14.92	.128	5.93	2.81	3.14	1.59	.19	.13	------	100.32	------	------
29345	3	5-15	[a]57.78	.51	3.67	12.85	.095	8.61	2.50	2.61	1.26	.15	.12	9.99	100.15	.950	5.42
			[b]64.21	.57	4.08	14.29	.105	9.58	2.78	2.90	1.40	.17	.14	------	100.13	------	------
29346	4	16+	[a]38.40	.27	2.09	7.57	.050	24.35	2.40	1.46	.87	.14	.14	21.98	99.72	067	18.55
			[b]49.24	.35	2.68	9.71	.069	31.21	3.07	1.87	.11	.18	.18	------	99.69	------	------

Sample No.	Horizon	Depth	Mechanical [3] Fine gravel (diameter 2-1 mm)	Coarse sand (diameter 1-0.5 mm)	Medium sand (diameter 0.5-0.25 mm)	Fine sand (diameter 0.25-0.1 mm)	Very fine sand (diameter 0.1-0.05 mm)	Silt (diameter 0.05-0.005 mm)	Clay (diameter 0.005-0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
29343	1	0-1½	3.8	5.1	2.1	10.5	27.8	36.1	14.6	100.0
29344	2	1½-4	1.8	4.8	2.8	11.8	29.2	28.0	21.7	100.1
29345	3	5-15	2.3	6.4	4.0	14.8	31.0	21.7	19.9	100.1
29346	4	15+	3.0	10.4	5.6	19.7	21.6	16.8	22.9	100.0

[1] Collected by C. F. Marbut.
[2] Analyzed by G. Edgington.
[3] Analyzed by A. A. White.

The percentage of alumina in the thin loose surface layer is a little less than that in the layer beneath. The percentage of nitrogen is high for the Gray soils but not so high as in the grassland soils as a rule. Carbonate is present from the surface downward, but it is very high below a depth of 15 inches.

The percentage of clay in the thin surface layer is only two-thirds as high as in the firm layer beneath, the field characteristics of the latter being well defined. The percentage of silt in the thin surface layer, however, is high, suggesting in this case also the influence of deposition.

The sa and sf ratios and the percentages of SiO_2 and of each of the principal sesquioxides when calculated to a total of 100 and also to constant percentages of CaO and MgO are shown in the several parts of Table 198.

TABLE 198.—*Sample of Gray soil, 12 miles south of Ely, Nev.*

Sample No.	Depth in inches	Ratios			Percentage calculated to a total of 100			Percentage calculated to constant percentages of CaO and MgO		
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3
29343	0– 1½	7.88	44.40	------	78.40	4.68	16.79	68.77	4.11	14.83
29344	1½– 4	7.61	42.22	------	77.74	4.87	17.37	68.26	4.28	15.25
29345	5–15	7.63	41.71	------	77.75	4.94	17.30	67.97	4.32	15.13
29346	16+	8.62	48.68	------	79.89	4.34	15.75	62.92	3.42	12.41

The sa ratios and the percentages obtained by both methods of recalculation indicate higher silica in layer 4 than in any other layer, not excepting the thin loose surface layer where it is high in the Dark-Brown, Brown, and Gray soils generally. The iron oxide-alumina ratios in the several layers are 27, 28, 28, and 27, showing that both iron oxide and alumina have maintained a uniform relative position throughout and indicating that silica is in this case the substance that has changed in the proportion present. Since the soil material is sedimentary, having been deposited as alluvial-fan material on a slope, from variable currents, the simplest explanation of this higher percentage of silica in layer 4 is that this is a layer with a higher amount of quartz than is present in the other layers. The mechanical analysis table tends to confirm this by showing nearly 40 per cent more fine sand in this layer than in any other.

The composition of a sample of a Gray soil from Delta, Utah, is shown in Table 199. This soil lies on the floor of ancient Lake Bonneville, and the material is heavy, containing up to 66 per cent of clay. The ½-inch surface layer is the "alkali crust," and the thin layer below it, extending to a depth of 3 inches, is the flocculated "alkali mulch." This layer contains a higher percentage of clay than any other layer.

TABLE 199.—*Composition of Gray soil, Delta, Utah* [1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28381	1	0– ½	[a]52.09	0.48	3.78	10.62	0.36	10.46	4.43	2.45	1.60	0.34	0.19	11.44	98.24	0.110	------
			[b]58.88	.54	4.27	12.10	.41	11.84	5.00	2.77	1.81	.38	.21	------	98.21	------	------
28382	2	½– 3	[a]49.05	.43	3.93	11.08	.31	9.96	4.15	2.65	3.28	.34	.72	14.05	99.95	.140	------
			[b]57.06	.50	4.57	12.89	.36	11.58	4.83	3.08	3.81	.40	.84	------	99.92	------	------
28383	3	3– 8	[a]49.70	.57	4.02	11.35	.02	10.87	4.73	2.49	.98	.24	.16	14.20	99.33	.060	------
			[b]58.00	.65	4.69	13.24	.02	12.68	5.51	2.90	1.14	.28	.19	------	99.30	------	------
28384	4	8–12	[a]46.40	.49	4.15	9.53	.02	14.55	4.34	2.09	1.16	.24	.23	16.70	99.90	.050	------
			[b]55.78	.59	4.98	11.45	.02	17.48	5.18	2.51	1.39	.29	.28	------	99.87	------	------
28385	5	12–30	[a]60.66	.51	2.75	7.43	.02	11.70	2.94	1.50	1.28	.20	.22	11.15	100.36	.000	------
			[b]68.27	.57	3.09	8.36	.02	13.16	3.31	1.69	1.44	.23	.25	------	100.39	------	------

Sample No	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28381	1	0– ½	0.3	0.5	1.1	7.7	10.7	17.2	62.4	99.9
28382	2	½– 3	.3	.5	.9	5.8	8.7	17.7	66.1	100.0
28383	3	3– 8	.3	.8	6.7	1.1	1.0	26.1	63.9	99.9
28384	4	8–12	.1	.2	.3	4.2	8.8	27.0	59.3	99.9
28385	5	12–30	.1	.4	1.3	23.3	30.2	34.1	10.5	99.9

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Aug. 3, 1920.
[3] Analyzed by L. T. Alexander.

The composition of two samples of soil from Harney Valley in central-eastern Oregon, a region having very low rainfall, are shown in Tables 200 and 201. These are young desert soils in which very little development has taken place.

TABLE 200.—*Composition of Gray soil, Harney County, Oreg.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28350	1	0– 2½	[a]64.80	0.87	4.42	15.85	0.082	3.03	1.41	2.30	3.00	0.13	0.050	4.02	99.96	0.100	------
			[b]67.51	.91	4.60	16.52	.085	3.16	1.47	2.40	3.12	.14	.050	------	99.97	------	------
28351	2	2½– 7	[a]64.70	.94	4.57	15.65	.085	3.24	1.16	2.20	3.10	.10	.080	3.70	99.43	.070	------
			[b]67.20	.87	4.74	16.27	.088	3.37	1.21	2.28	3.22	.10	.080	------	99.44	------	------
28353	3	7–13	[a]58.80	.91	7.77	16.50	.062	2.87	1.88	1.88	2.72	.15	.034	5.15	98.72	.020	------
			[b]62.06	.96	8.20	17.40	.065	3.03	1.98	1.98	2.87	.16	.036	------	98.75	------	------
28354	4	13–24	[a]60.00	.94	7.34	16.00	.072	3.76	1.92	1.74	2.88	.16	.065	5.10	99.98	.010	------
			[b]63.22	.99	7.73	16.85	.076	3.96	2.02	1.83	3.03	.17	.068	------	99.95	------	------
28355	5	24–42	[a]52.80	.79	5.43	13.85	.045	9.74	3.30	1.63	2.36	.16	.065	9.64	99.82	.020	------
			[b]58.47	.87	6.01	15.33	.050	10.78	3.65	1.80	2.61	.18	.072	------	99.82	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28350	1	0– 2½	0.0	1.0	1.0	12.1	17.9	55.1	13.0	100.1
28351	2	2½– 7	.0	.9	.9	9.6	22.4	54.9	11.5	100.2
28353	3	7–13	.8	2.0	1.6	13.5	12.0	38.0	32.3	100.2
28354	4	13–24	1.0	4.0	3.0	25.0	10.9	40.5	15.6	100.0
28355	5	24–42	.9	7.8	5.6	34.9	15.2	28.7	6.1	99.2

[1] Collected by C. F. Marbut.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Apr. 7, 1920.
[3] Analyzed by A. A. Riley.

TABLE 201.—*Composition of Gray soil, Crane, Harney County, Oreg.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28346	1	0– 2	[a]61.00	0.81	5.08	15.10	0.069	4.55	2.26	2.42	2.38	0.34	0.051	6.20	100.26	0.150	------
			[b]65.04	.87	5.42	16.10	.074	4.85	2.41	2.58	2.54	.36	.054	------	100.29	------	------
28347	2	2– 5	[a]61.20	.88	3.83	14.50	.059	4.67	2.16	2.62	2.36	.26	.048	6.27	98.86	.090	------
			[b]65.32	.94	4.09	15.48	.063	4.98	2.31	2.80	2.52	.28	.051	------	98.83	------	------
28348	3	5–17	[a]58.70	.73	4.96	14.45	.055	5.67	2.72	2.54	2.88	.27	.089	6.57	99.64	.070	------
			[b]62.88	.78	5.31	15.46	.059	6.07	2.91	2.72	3.09	.29	.095	------	99.67	------	------
28349	4	18–36	[a]65.30	.77	4.10	15.70	.094	2.98	1.61	2.38	2.78	.14	.054	3.65	99.55	.090	------
			[b]67.80	.80	4.25	16.29	.098	3.08	1.67	2.47	2.89	.15	.056	------	99.58	------	------

[1] Collected by C. F. Marbut. [2] Analyzed in the division of soil chemistry, Bureau of Soils, Apr. 7, 1920.

TABLE 201.—*Composition of Gray soil, Crane, Harney County, Oreg.*—Continued

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28346	1	0– 2	0.3	2.0	2.2	29.0	23.1	33.1	9.7	99.4
28347	2	2– 5	.6	1.9	1.8	17.2	20.9	39.4	18.2	100.0
28348	3	5–17	.4	3.2	2.6	24.6	19.4	32.3	17.3	99.8
28349	4	18–36	.0	1.0	1.2	14.4	19.2	55.6	8.8	100.2

[3] Analyzed by A. A. Riley.

COMPOSITION OF PACIFIC COAST SOILS

Practically no work has been done in the laboratories of the Bureau of Chemistry and Soils in the determination of the composition of Pacific coast soils. In Tables 202, 204, and 206, the chemical and mechanical composition of two Podzolic soils from Oregon and one from northern Idaho are given.

The chemical and mechanical composition of material from a profile of Helmer silt loam from Kootenai County, Idaho, are shown in Table 202. This soil has developed under forest cover and a rainfall of about 30 inches, most of which falls in winter. It has developed from the bed of silt, or loess, that covers eastern Washington, northeastern Oregon, and northwestern Idaho.

TABLE 202.—*Composition of Helmer silt loam, Worley, Kootenai County, Idaho* [1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
540817	A_1	0–12	[a]70.36	1.02	4.23	13.84	0.066	1.69	1.08	2.34	1.95	0.25	0.16	3.01	100.00	0.060	------
			[b]72.53	1.05	4.36	14.27	.068	1.74	1.11	2.41	2.01	.26	.16	------	99.97	------	------
540818	A_2	12–18	[a]72.14	1.06	3.88	14.02	.037	1.60	1.06	2.09	2.03	.13	.13	1.82	100.00	.014	------
			[b]73.49	1.08	3.95	14.27	.038	1.63	1.08	2.13	2.07	.13	.13	------	100.00	------	------
540819	B_1	18–30	[a]68.80	.97	5.30	15.26	.040	1.67	1.28	2.14	1.96	.36	.07	2.15	100.00	.014	------
			[b]70.31	.99	5.42	15.59	.040	1.71	1.31	2.19	2.00	.37	.07	------	100.00	------	------
540820	B_2	30–36	[a]66.83	.94	5.97	16.31	.057	1.72	1.33	2.01	1.81	.13	.09	2.80	100.00	.017	------
			[b]68.75	.97	6.14	16.78	.059	1.77	1.37	2.07	1.86	.13	.09	------	99.99	------	------

Sample No.	Horizon	Depth	Mechanical [3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
540817	A_1	0–12	0.3	1.1	0.7	4.1	17.0	65.9	10.9	100.0
540818	A_2	12–18	.4	1.6	.8	3.9	19.3	66.1	8.1	100.2
540819	B_1	18–30	.0	1.2	.8	5.2	18.4	57.8	16.7	100.1
540820	B_2	30–36	.0	1.3	.6	6.0	18.1	56.8	17.3	100.1

[1] Collected by H. G. Lewis.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, Dec. 4, 1920.
[3] Analyzed by A. A. Riley.

The several ratios and the molecular equivalent composition in SiO_2, Fe_2O_3, Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 203.

TABLE 203.—*Sample of Helmer silt loam, Kootenai County, Idaho*

Sample No.	Depth in inches	Ratios			Molecular equivalent composition			
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
540817	0–12	8.64	44.08	0.637	1.202	0.0273	0.1396	0.089
540818	12–18	8.75	49.30	.609	1.218	.0241	.1396	.085
540819	18–30	7.67	34.37	.563	1.166	.0339	.1525	.086
540820	30–36	6.96	29.67	.508	1.107	.0384	.1641	.083

The sa ratios show some accumulation of alumina in the B_1 horizon, extending from 18 to 30 inches, the molecular equivalent showing the same, but the latter indicates somewhat greater accumulation in B_2 though no comparison can be made with C since it was not sampled.

The sf ratio indicates iron oxide accumulation in B_1 in excess of that in B_2 but the molecular equivalent ratio, which seems a little more reliable, shows higher content in B_2.

The content of bases, according to ba ratio, is greatest in A_1 and least in B_2 confirmed in this case by the molecular equivalent composition, but the differences are very slight.

This is apparently a ground water soil, the B_1 horizon seemingly corresponding to the level of ground water. A_2 is a grayish horizon, but the leaching is very slight. This is shown by comparing it with the Miami silt loam (p. 35.)

A more characteristic soil of the forested region of the northwest, but one whose composition from the surface well into the C horizon has not yet been determined, is Cascade silt loam. The chemical and mechanical composition of material from the solum layers of a profile in Multnomah County, Oreg., are shown in Table 204.

TABLE 204.—*Composition of Cascade silt loam, Multnomah County, Oreg.*[1]

Sample No.	Horizon	Depth	Chemical [2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28398	A_1	0– 4½	[a]70.40	1.08	3.90	13.14	0.070	1.78	0.97	2.11	1.98	0.16	0.21	4.25	100.05	0.080	------
			[b]73.50	1.13	4.07	13.73	.070	1.86	1.01	2.20	2.07	.17	.22	------	100.03	------	------
28399	A_2	4½–12	[a]71.00	1.25	4.22	13.60	.070	1.97	.98	2.31	2.15	.12	.11	3.14	100.92	.040	------
			[b]73.29	1.29	4.36	14.04	.070	2.03	1.01	2.39	2.22	.12	.11	------	100.93	------	------
28400	B	12–36	[a]67.30	1.25	5.87	15.49	.072	1.60	1.06	2.17	2.12	.20	.22	3.63	100.98	.022	------
			[b]69.81	1.30	6.09	16.06	.075	1.66	1.10	2.25	2.20	.21	.23	------	100.99	------	------

[1] Collected by E. J. Carpenter. [2] Analyzed in the division of soil chemistry, Bureau of Soils, Dec. 4, 1920.

TABLE 204.—*Composition of Cascade silt loam, Multnomah County, Oreg.*

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28398	A_1	0 – 4½	0.0	1.4	1.1	1.7	9.7	67.1	18.9	99.9
28399	A_2	4½–12	.2	1.9	1.3	1.8	10.6	66.0	18.2	100.0
28400	B	12 –36	.0	.8	.6	1.2	10.1	65.0	22.3	100.0

[3] Analyzed by L. T. Alexander.

The several ratios and the molecular equivalent composition in SiO_2, Fe_2O_3, Al_2O_3, and of the combined alkalies and alkaline earths are shown in Table 205.

TABLE 205.—*Sample of Cascade silt loam, Multnomah County, Oreg.*

Sample No.	Depth in inches	Ratios			Molecular equivalent composition			
		sa	sf	ba	SiO_2	Fe_2O_3	Al_2O_3	Alkalies and alkaline earths
28398	0 – 4½	9.10	47.85	0.668	1.218	0.0255	0.1245	0.090
28399	4½–12	8.87	44.54	.561	1.215	.0273	.1373	.097
28400	12 –36	7.38	30.37	.565	1.157	.0381	.1571	.089

The surface layer of 4 inches has about 5 per cent more silica than the layer beween 12 and 36 inches, but the second and third layers are almost exactly alike in the content of their base molecules, whereas the surface layer contains only about 8 per cent fewer base molecules than the second layer. Both the first and second layers seem to have more base molecules than the third.

This is a Podzolic soil, but podzolization is very slight.

The composition of a profile of Holland coarse sandy loam from southwestern Oregon is shown in Table 206. The parent rock is granite. The soil has developed on smooth, gentle slopes where it is subjected to seep water from higher up the slope or from temporary ground water. The subsoil below a depth of 10 inches, is indurated when dry but only very slightly so when wet. It is apparent that the material below a depth of 10 inches is more thoroughly leached than that above. This is indicated by the alkalies and alkaline earths, probably the effect of ground water. A considerable part of the sand is feldspathic.

TABLE 206.—*Holland coarse sandy loam, Josephine County, Oreg.*[1]

Sample No.	Horizon	Depth	Chemical[2]														
			SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	Ignition loss	Total	N	CO_2 from carbonates
		Inches	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
28366	A_1	0– 2	[a]55.81	0.68	1.65	22.69	0.15	2.21	1.13	2.42	1.28	0.59	0.30	8.82	97.73	0.020	------
			[b]61.36	.75	1.81	24.93	.16	2.43	1.24	2.66	1.41	.65	.33	------	97.73	------	------
28367	A_2	2–10	[a]59.09	.79	1.75	25.52	.09	2.00	.72	2.59	1.94	.20	.03	4.09	98.81	.090	------
			[b]61.67	.82	1.83	26.63	.09	2.09	.75	2.70	2.02	.21	.03	------	98.84	------	------
28368	B_1	10–24	[a]51.31	.69	2.40	32.24	.09	1.22	.44	1.63	1.47	.16	.09	6.40	98.14	.070	------
			[b]54.90	.74	2.57	34.50	.10	1.31	.47	1.74	1.57	.17	.10	------	98.17	------	------
28369	B_2	24–36	[a]52.48	.38	1.66	32.03	.04	1.16	.69	2.02	1.25	.14	.11	4.28	96.24	.070	------
			[b]54.92	.40	1.74	33.50	.04	1.21	.72	2.11	1.31	.15	.12	------	96.22	------	------

Sample No.	Horizon	Depth	Mechanical[3]							
			Fine gravel (diameter 2–1 mm)	Coarse sand (diameter 1–0.5 mm)	Medium sand (diameter 0.5–0.25 mm)	Fine sand (diameter 0.25–0.1 mm)	Very fine sand (diameter 0.1–0.05 mm)	Silt (diameter 0.05–0.005 mm)	Clay (diameter 0.005–0.000 mm)	Total mineral constituents
		Inches	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28366	A_1	0– 2	14.8	18.7	8.5	16.3	10.3	20.5	10.9	100.0
28367	A_2	2–10	11.0	16.7	8.4	15.2	10.3	20.7	17.7	100.0
28368	B_1	10–24	8.0	13.0	6.4	12.6	8.8	19.2	32.1	100.1
28369	B_2	24–36	11.7	15.4	7.6	14.5	10.0	17.6	23.2	100.0

[1] Collected by A. E. Kocher.
[2] Analyzed in the division of soil chemistry, Bureau of Soils, July, 1921.
[3] Analyzed by L. T. Alexander.

METHOD OF SOIL ANALYSIS USED IN THE DIVISION OF SOIL CHEMISTRY AND PHYSICS, BUREAU OF CHEMISTRY AND SOILS

By W. O. Robinson, Chemist, Division of Soil Chemistry and Physics, Soil Investigations, Bureau of Chemistry and Soils

INTRODUCTION

The methods used in the analyses of the soils herein reported follow closely those developed by Hillebrand (*9*) for the analysis of rocks. The total constituents were determined by fusion with sodium carbonate. After a soil has been ignited, it can be treated analytically the same as a rock powder. The methods used in the division are described in detail in Circular 139, United States Department of Agriculture, and will be briefly outlined in the following pages.

PREPARATION OF THE SAMPLE

The sample was received in the laboratory in the air-dried condition. The clods, when present, were crushed with a hardwood rolling-pin. The sample was then passed through a 2-millimeter sieve. Stones not passing through were rejected. The sample was well mixed and quartered down to 25 to 50 grams, depending on the number and character of the determinations to be made. The sample to be examined was then ground in an agate mortar and passed through a silk bolting cloth of 100 meshes to the linear inch, after which it was thoroughly mixed.

MOISTURE DETERMINATION

About 2 grams of soil were weighed in a shallow weighing dish provided with an accurately fitting stopper. The bottle and contents were dried overnight in a drying oven regulated at 110° C.

LOSS ON IGNITION

From 0.5 gram to 1 gram of the air-dried sample (depending on the iron and aluminum content) was accurately weighed into a 15-milliliter platinum crucible. This was heated in an electric furnace or over a Bunsen burner to about 800° C. and held there one-half hour. When the Bunsen burner was used, the cover of the crucible was so adjusted that the crucible contents had free access to the air. After cooling and weighing, the crucible and contents were ignited an additional 15 minutes to check the first weight. The crucible and contents were reserved for the determination of the major elements; that is, silicon, aluminum, iron, titanium, calcium, and magnesium.

FUSION WITH SODIUM CARBONATE

The residue from the loss on ignition determination was mixed with five times its weight of the purest sodium carbonate [25] obtainable. The covered crucible was heated cautiously until the flux had melted and the fusion was quiet. The full heat of a good Bunsen burner or moderate heat of a blast lamp was applied for 10 minutes more. While the contents of the crucible were still molten, the crucible was whirled with the tongs in such a manner as to congeal the contents on the sides, leaving as little as possible on the bottom. The crucible was then rapidly cooled on a slab of iron or alberene, and the contents were detached immediately from the crucible by inverting it over a 250-milliliter beaker or large platinum dish and rolling it between the fingers with gentle pressure against the sides. The melt was thoroughly disintegrated with hot water. After disintegration of the melt, the material adhering to the crucible and cover was thoroughly washed into the dish, and a few drops of ethanol added to reduce the green manganate.

DETERMINATION OF SILICA

When the greenish color of the disintegrated mass had disappeared, 15 milliliters of pure concentrated hydrochloric acid was added slowly to the covered dish. After the reaction had ceased, the material adhering to the cover and sides of the dish was washed into the dish and the contents evaporated to dryness on the steam bath. The evaporation was continued until the silica gel was sufficiently dehydrated. The residue was taken up with 15 milliliters of strong hydrochloric acid and hot water and filtered and washed till practically free from chlorides. The filtrate was evaporated to dryness in order to precipitate any silica not retained in the first precipitation. The residue was taken up again with 15 milliliters of concentrated hydrochloric acid and hot water, filtered, and washed free from chlorides into a 250-milliliter beaker. The two silica precipitates were combined and ignited in the same crucible in which the fusion was made. The silica precipitates were ignited slowly at first to avoid mechanical loss. After the carbon was thoroughly burned from the precipitate, the silica was ignited for 20 minutes to one-half hour at the full temperature of the blast lamp. The weights were checked by 10-minute periods of blasting to practically constant weight. When a nearly constant weight was obtained the silica was moistened with water, from 6 to 8 milliliters of hydrofluoric acid and a few drops of sulphuric acid were added, and the contents of the crucible were evaporated to dryness, cautiously ignited, and weighed. If the residue was more than 2 or 3 milligrams, the hydrofluoric acid treatment was repeated. The loss in weight was taken as the weight of the silica. The crucible and contents were reserved for the ignition of the iron group.

DETERMINATION OF IRON, ALUMINUM, AND TITANIUM

The filtrate from the silica determination, in a 250-milliliter beaker, was nearly neutralized with a solution of ammonia, using the precipitate as an indicator. The slightly acid solution was heated to boiling and precipitated with a slight excess of ammonia, boiled a minute or so and filtered through an 11-centimeter filter paper into a 400-milliliter beaker. It was washed only slightly in this first precipitation. The filter and contents were transferred to the beaker in which the precipitation was made, 10 milliliters of strong hydrochloric acid and water were added, and the filter paper was macerated by two glass rods. After adding enough water to make the volume up to about 150 milliliters, the iron group was precipitated as before and washed thoroughly. The last washings were made with water containing 1 per cent of ammonium nitrate. The precipitate was transferred on the filter paper to the crucible containing the residue from the silica determination and ignited to constant weight.

The iron group precipitate was dissolved by fusion with 5 to 7 grams of potassium pyrosulphate. The resulting melt was dissolved, after cooling, in 4 milliliters of strong sulphuric acid and water, taking care to keep the volume under 150 milliliters. The solution, in an iron-reduction flask, was thoroughly reduced by hydrogen sulphide, the excess hydrogen sulphide boiled off in a stream of carbon dioxide, and the iron titrated with standard potassium-permanganate solution.

The liquid from the iron titration was evaporated to 50 to 75 milliliters, 10 milliliters of concentrated sulphuric acid and a few drops of hydrogen peroxide were added, the solution was made up to 100 milliliters, and the color was compared with a standard titanium solution treated in the same manner.

PRECIPITATION OF THE AMMONIUM-SULPHIDE GROUP

The filtrates from the iron group were evaporated to slightly less than 100 milliliters in a platinum dish, and the liquid was transferred to a wide-mouthed Erlenmeyer flask. From 2 to 3 milliliters of strong ammonia were added and hydrogen sulphide was passed in until the liquid was saturated. From 2 to 3 milliliters of strong ammonia were again added and the flask stoppered and allowed to stand overnight. The precipitated manganese, copper, zinc, etc., were filtered off and washed with ammonia and ammonium-sulphide solution.

DETERMINATION OF CALCIUM

An excess of recently dissolved ammonium oxalate was added to the hot filtrate from the ammonium sulphide, which did not exceed 150 milliliters in volume, and the precipitate was digested several hours on a steam bath. After cooling it was filtered through the finest filter paper. The precipitate was ignited to render the coprecipitated platinum insoluble. It was then dissolved in hydrochloric acid, reprecipitated as oxalate, ignited at the temperature of the blast lamp, and weighed. The combined filtrates were reserved for the magnesium determination.

DETERMINATION OF MAGNESIUM

The combined filtrates from the calcium determination were evaporated, if necessary, to 175 milliliters. An excess of sodium hydrogen phosphate was added to the cool solution and the mixture stirred. Enough strong ammonia was slowly added to make the solution about 5 per cent with respect to ammonia, and the stirring was continued. The precipitate was allowed to stand overnight in a cool place. It was then filtered and washed with 2.5 per cent ammonia. The precipitate was dissolved in hydrochloric acid and precipitated with a slight excess of sodium hydrogen phosphate in a solution containing about 5 per cent ammonia. It was allowed to stand two hours or longer in a cool place, then filtered and washed with 2.5 per cent ammonia till free from chlorides. The precipitate was dried and ignited slowly, and finally burned white with the Bunsen burner. The magnesium precipitate was corrected for the calcium it invariably contained by dissolving the magnesium precipitate in dilute sulphuric acid, precipitating the calcium as sulphate in 95 per cent alcohol and determining the calcium as oxalate.

DETERMINATION OF POTASSIUM AND SODIUM

The well-known J. Lawrence Smith method (*17*) was used for the determination of these elements. It has not been easy to obtain ammonium chloride and calcium carbonate sufficiently free from alkalies to obtain satisfactory determinations.

DETERMINATION OF MANGANESE AND PHOSPHORUS

Two grams of soil were treated with a few milliliters of nitric acid in a platinum dish, and, after evaporating to dryness, the mass was ignited at the full heat of the Bunsen burner for a full half hour. The ignited residue was treated with 20 milliliters of strong hydrofluoric acid and from 5 to 10 milliliters of nitric acid and allowed to stand overnight. It was then evaporated to dryness. About 20 milliliters of nitric acid were then added and the solution evaporated to dryness. The addition of nitric acid and evaporation to dryness were then repeated twice in order to free the material from fluorides. The residue was taken up with water to which a few drops of sulphurous acid was added to dissolve any manganese dioxide that might have formed, 5 milliliters of nitric acid were added, and the solution was filtered into a 100-milliliter flask and made up to volume.

Twenty-five milliliters of this solution were taken for the manganese determination. The manganese in this solution was determined colorimetrically, the color being developed by ammonium persulphate and silver nitrate or by potassium periodate.

The remaining 75 milliliters were taken for the phosphorus determination. To this solution enough ammonia was added to partly precipitate the iron, the solution was cleared with a few drops of nitric acid, then enough nitric acid was added to make the solution 4 per cent with respect to this acid. The phosphorus was precipitated from this solution in the usual manner and estimated gravimetrically as magnesium pyrophosphate. When the phosphomolybdate precipitate was dissolved in ammonia, it frequently happened that some of the precipitate would fail to dissolve. If the addition of a few crystals of citric acid did not dissolve it, the precipitate was filtered off, fused with sodium carbonate, and the phosphorus obtained from it added to the main phosphorus precipitate.

---

[25] Since five times as much flux as soil is used, an impurity present in the flux in quantities of 0.01 per cent would cause an error of 0.05 per cent in the determination

DETERMINATION OF SULPHUR

One or two grams of soil were fused with sodium carbonate and a little niter in an electric furnace to avoid sulphur contamination from the gas. The fused mass was thoroughly disintegrated with water, filtered, and washed with a dilute solution of sodium carbonate. The sulphur was precipitated and estimated as barium sulphate in the filtrate, generally without the previous separation of silica.

DETERMINATION OF NITROGEN

The nitrogen content was determined by the Gunning method as modified by Hibbard.

DETERMINATION OF ORGANIC MATTER

The organic matter was estimated by combustion, multiplying the carbon dioxide so obtained by the Van Bemmelen factor of 0.471 to reduce to organic matter.

DETERMINATION OF COMBINED WATER

The combined water was estimated by subtracting the percentage of organic matter from the total loss on ignition. Any errors that exist in the application of the Van Bemmelen factor for organic matter will be found in the percentage found for combined water.

DETERMINATION OF CARBON DIOXIDE FROM CARBONATES

Since carbonates are not generally found in soils, a qualitative test for carbonates always preceded the quantitative determination. When present, the carbonates were determined by boiling the soil in hydrochloric acid diluted with an equal volume of water and weighing the carbon dioxide evolved.

LIMITS OF ERROR IN THE ANALYSIS

All analytical results are a compromise, usually arrived at by taking advantage of the solubility of compounds to be removed and the relative insolubility of the precipitate to be purified and determined. No substance is absolutely insoluble, and when relatively large quantities of soluble substances have to be washed from a relatively small quantity of a nearly insoluble compound, an appreciable proportion of the latter may be dissolved before the former has been entirely removed. As an example, after the removal of the silica there remains an acid solution of the bases with a large excess of sodium chloride. In the precipitation of the iron group, considerable ammonia and ammonium chloride are added. In the precipitation of calcium as calcium oxalate, it is necessary to remove the chlorides by washing, and, as the calcium oxalate is slightly soluble, some of the latter is lost and may or may not be recovered later in the analysis. The personal factor of judgment in the termination of the washing comes into play and will explain many discrepancies.

The analyses of soils stated in the tables are commonly given to the second decimal place, and the figures for manganese and nitrogen are given to the third decimal place. This is common practice in stating soil analyses.

However, it is not to be understood that the analyses necessarily possess this accuracy.

As a result of the comparison of analyses of the same soil by different analysts in this laboratory, certain allowable limits of error are given. For the soil of average composition, the following limits have been considered satisfactory: SiO_2, 0.50 per cent; TiO_2, 0.05 per cent; Al_2O_3, 0.30 per cent; Fe_2O_3, 0.15 per cent; MnO, 0.003 per cent; CaO, 0.10 per cent; MgO, 0.15 per cent; K_2O, 0.05 per cent; Na_2O, 0.10 per cent; P_2O_5, 0.04 per cent; SO_3, 0.05 per cent; N, 0.005 per cent; and organic matter, 0.20 per cent. The figures are in percentage of the soil and not in percentage variation. Duplicates by the same analyst should, of course, agree more closely. In the variations mentioned it is probable that one extreme is higher than the correct figure and the other lower. The deviation from the correct figure is therefore less than the extremes given.

Several factors contribute to the errors observed. These are as follows: Lack of uniformity of sample, impure reagents, contamination from glassware or other utensils, and finally the error incident to the method of analysis, which may be of both a personal and a chemical character. All errors except the last may be nearly eliminated by care and by blank determintions.

One reason for calling attention to these limits of error is the tendency to attach too much importance to differences of a few pounds when the analyses are stated in pounds per acre.

Assuming that an acre of soil 6 inches deep weighs 1,750,000 pounds, the limits of error expressed in pounds per acre would be as follows:

	Pounds per acre
CaO (limit 0.10 per cent)	1, 750
K_2O (limit 0.05 per cent)	875
P_2O_5 (limit 0.04 per cent)	700

Stated in another way, it would appear as follows: Suppose a soil on analysis gave CaO, 0.30 per cent; K_2O, 0.50 per cent; and P_2O_5, 0.08 per cent; with the above limits of error the composition might be:

	Per cent
CaO	0. 35 or 0. 25
K_2O	0. 525 or 0. 475
P_2O_5	0. 10 or 0. 06

Or in pounds per acre:

	Pounds
CaO	6, 125 or 4, 735
K_2O	9, 188 or 8, 312
P_2O_5	1, 750 or 1, 050

It is plain that too much significance should not be attached to differences of a few hundred pounds when expressed in pounds per acre.

The use of standard samples and duplicate determinations are the analyst's guard against errors. Another important guard lies in the summation, which should not be below 99.5 per cent or above 100.75 per cent. In the case of soils, a low summation generally means mechanical loss of silica rather than the presence of undetermined elements. Mechanical loss during the loss on ignition determination will not, of course, be detected in the summation. The entire error in this case will be in the loss on ignition.

LITERATURE CITED

(1) Anderson, M. S., and Byers, H. G.
1930. CHARACTER OF THE COLLOIDAL MATERIALS IN THE PROFILES OF CERTAIN MAJOR SOIL GROUPS. U. S. Dept. Agr. Tech. Bul. 228, 24 p.

(2) Atterberg, A.
1912. DIE MECHANISCHE BODENANALYSE UND DIE KLASSIFIKATION DER MINERAL-BODEN SCHWEDENS. Internatl. Mitt. Bodenk. 2:[312–]342, illus.

(3) Campbell, J. M.
1917. LATERITE—ITS ORIGIN, STRUCTURE, AND MINERALS. Mining Mag. 17:67–77, 120–128, 171–179, 220–229.

(4) Denison, I. A.
1930. THE CHEMICAL COMPOSITION OF COLLOIDAL MATERIAL ISOLATED FROM THE HORIZONS OF VARIOUS SOIL PROFILES. Jour. Agr. Research 40:469–483.

(5) Fowler, E. D.
1927. IRON ACCUMULATION IN SOILS OF THE COASTAL PLAIN OF THE SOUTHEASTERN UNITED STATES. First Internatl. Cong. Soil Sci. Proc. and Papers 4:435–441.

(6) Frosterus, B.
1924. DIE KLASSIFIKATION DER BODEN UND BODENARTEN FINNLANDS. Geol. Komm. Finland, Agrogeologiska Meddel. No. 18, 39 p., illus. Helsingfors, Finland.

(7) ———
1924. MEMOIRES SUR LA NOMENCLATURE ET LA CLASSIFICATION DES SOLS. Internatl. Comm. Soil Sci. Geol. Survey Finland.

(8) Harrassowitz, H. I.
1926. LATERIT, MATERIAL UND VERSUCH, ERDGESCHICHTLICHER AUSWERTUNG. Fortschr. Geol. u. Paläontol. Bd. 4, Heft. 14, p. 253–566.

(9) Hillebrand, W. F.
1919. THE ANALYSIS OF SILICATE AND CARBONATE ROCKS. U. S. Geol. Survey Bul. 700, 285 p., illus. (Rev. and enl. ed. of Bul. 422.)

(10) Holmes, R. S., and Edgington, G.
1930. VARIATIONS OF THE COLLOIDAL MATERIAL EXTRACTED FROM THE SOILS OF THE MIAMI, CHESTER, AND CECIL SERIES. U. S. Dept. Agr. Tech. Bul. 229, 24 p., illus.

(11) Marbut, C. F.
1922. SOIL CLASSIFICATION REPORT. Amer. Assoc. Soil Survey Workers Ann. Rpt. 2:24–33.

(12) ———
1929. THE RELATION OF SOIL TYPE TO ORGANIC MATTER. Jour. Amer. Soc. Agron. 21: 943–950.

(13) ——— Bennett, H. H., Lapham, J. E., and Lapham, M. H.
1913. SOILS OF THE UNITED STATES. U. S. Dept. Agr., Bur. Soils Bul. 96, 791 p., illus.

(14) Merrill, G. P.
1906. A TREATISE ON ROCKS, ROCK-WEATHERING, AND SOILS. 400 p., illus. New York and London.

(15) Robinson, W. O., and Holmes, R. S.
1924. THE CHEMICAL COMPOSITION OF SOIL COLLOIDS. U. S. Dept. Agr. Bul. 1311, 42 p.

(16) Shantz, H. L., and Zon, R.
1924. THE PHYSICAL BASIS OF AGRICULTURE. SECTION E, NATURAL VEGETATION. U. S. Dept. Agr., Atlas of American Agriculture, pt. 1, Sec. E., 29 p., illus.

(17) Smith, J. L.
1871. ON THE DETERMINATION OF THE ALKALIES IN SILICATES BY IGNITION WITH CARBONATE OF LIME AND SAL-AMMONIAC. Amer. Jour. Sci. and Arts (3) 1:269–275, illus.

(18) Villar, E. H. del.
1929. GEOBOTANICA. p. 173, Editorial Labor. S. A. Barcelona.

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

ATLAS

OF

AMERICAN AGRICULTURE

PREPARED UNDER THE SUPERVISION OF O. E. BAKER, AGRICULTURAL ECONOMIST
BUREAU OF AGRICULTURAL ECONOMICS, H. C. TAYLOR, CHIEF

THE PHYSICAL BASIS OF AGRICULTURE

NATURAL VEGETATION

GRASSLAND AND DESERT SHRUB

BY
H. L. SHANTZ
PHYSIOLOGIST, BUREAU OF PLANT INDUSTRY

FORESTS

BY
RAPHAEL ZON
FOREST ECONOMIST, FOREST SERVICE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

CONTENTS.

THE NATURAL VEGETATION OF THE UNITED STATES.

INTRODUCTION.

The United States, which includes within its borders a wide range of climatic, physiographic, and soil differences, presents a very great diversity in natural vegetation. The vegetation ranges from the deciduous forests of the East to the sparse grasslands of the Great Plains, from the alpine meadows among the snow-capped peaks of the Rockies, Sierra, Cascade, and Olympic ranges to the subtropical forests of southern Florida, and from the luxuriant forests of the Northwest to the almost barren deserts of southeastern California. It is difficult to present a clear and coherent picture of such complex vegetation. Of the several proposed classifications some are based on purely geographic lines, other groupings are based on physiographic regions, and still others on the requirements of temperature or water. The present description is based largely on the distinctive features of the vegetation itself.

In classifying the vegetation no attempt has been made to correlate it with geography, physiography, or with climatic or other physical factors. The natural vegetation is the expression of environment, it is the integration of all climatic and soil factors, past as well as present, and, therefore, if it can be distinctly and clearly indicated, provides often a better basis for a classification of environments than any one factor or set of factors. The forms of vegetation here described are not merely aggregations of species but are biological communities characterized by certain similarity in their biological aspect, in their environment, in their past history, and in their ultimate development. The biological unit is thus made the basis of classification and the environment is measured in terms of vegetation, and not the vegetation in terms of temperature, moisture, evaporation, or any other factor. Since the attempt to correlate the vegetation with any one factor or set of factors has been avoided, the temptation to force the vegetation to correspond to the assumed controlling factors of its distribution has been done away with and the establishment of real differences in the vegetation itself made easier.

The natural vegetation of a country, when properly analyzed and classified, may serve a very concrete and practical purpose. As a new country becomes settled the natural vegetation must be replaced gradually by agricultural crops, orchards, pastures, and man-made forests. The suitability of the virgin land for various crops is usually indicated very clearly by the natural vegetation. After a correlation is established between the different forms of natural vegetation and various agricultural or forest crops, it provides a means of dividing the country into natural regions of plant growth, which can be used as indicators of the potential capabilities of the virgin land for agriculture and forest production.

In preparing the accompanying map, published vegetation studies and maps, local floras, soil, geological, land, military, and biological surveys, and Forest Service maps and reports have been consulted. The selected bibliography does not cover the sources from which this map is drawn. It is chosen to supplement the information here presented and lack of space alone has prevented the inclusion of many important papers. A large number of persons intimately acquainted with different regions have freely given advice and criticism.[1] Although the aim has been to make the map as accurate as possible, it must still be regarded as preliminary. If it will stimulate further and more detailed studies in the classification of the natural vegetation by states or smaller units, the work of preparing it will be fully justified. Such studies will make possible the preparation at some future time of a more accurate and detailed map of our natural vegetation. On a map of small scale and with lack of abrupt vegetation changes, the plant cover of certain localities, especially on the border line between two types, might be classified differently by different persons. It is necessarily a generalized map, and many may find that the vegetation represented does not exactly tally with that with which they are intimately familiar in certain localities. An attempt is made only to indicate such vegetation as gives character to the area, necessarily omitting smaller areas of type differing from that of the region. In discussing each unit of vegetation the more important variations have been considered, although they could not be indicated on the map itself. Not the least difficult task in preparing the map has been the classification of the vegetation and the determination how far the map should show subdivisions. Gradual changes in vegetation, such as occur in passing from the humid prairie to the arid grassland of the high plains, are as important as the more abrupt ones. Where such changes occur a wide transition zone is found. Transition zones have not been shown on the map, but the types have been separated by definite lines indicating as nearly as possible the division between the two areas.

[1] The authors are particularly under obligation to the following persons whose sympathetic criticism and suggestions greatly helped them in their work: A. E. Aldous, L. H. Bailey, O. E. Baker, C. R. Ball, C. G. Bates, H. H. Bennett, S. F. Blake, F. E. Clements, F. E. Cobb, John S. Cole, E F. Frothingham, F. C. Gates, David Griffiths, Roland Harper, A. S. Hitchcock, E. R. Hodson, T. H. Kearney, C. F. Korstian, W. E. McLendon, C. F. Marbut, F. J. Marschner, W. R. Mattoon, Edw. N. Munns, G. A. Pearson, R. L. Piemeisel, C. W. Piper, J. F. Preston, J. N. Rose, W. E. Safford, W. N. Sparhawk, J. W. Stokes, Geo. B. Sudworth, I. E. Tidestrom, J. J. Thornber, R. H. Weidman, and E. O. Wooton.

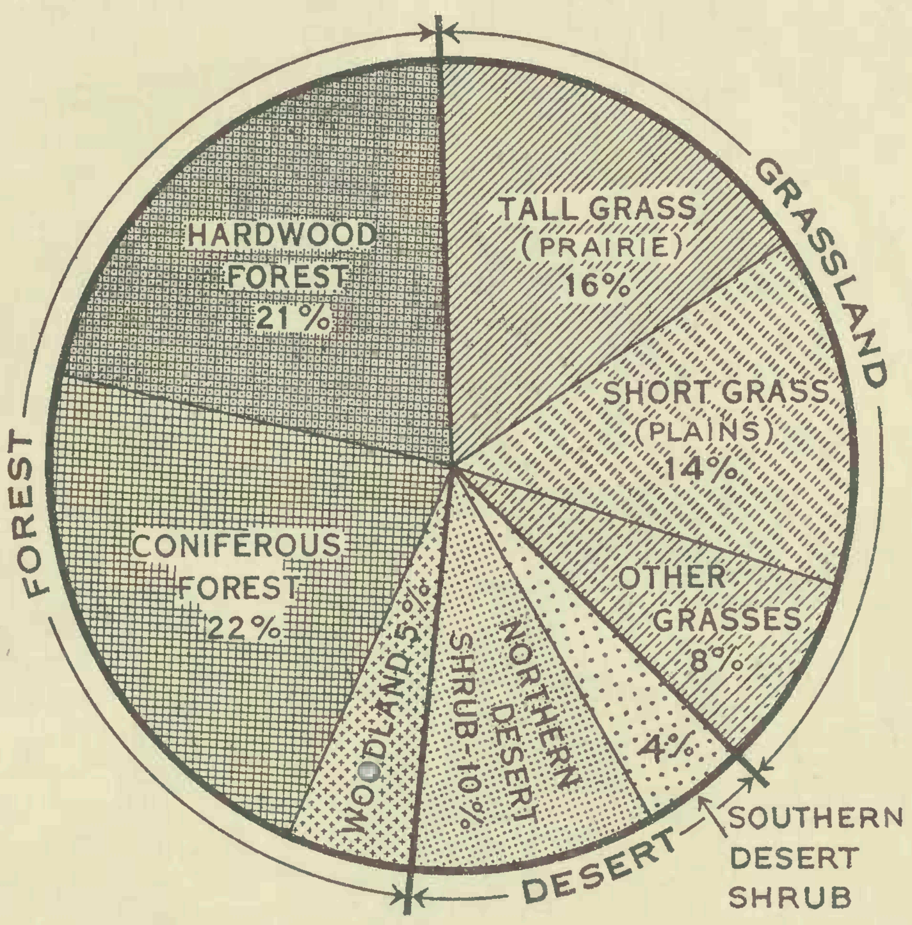
GENERAL OUTLINE OF THE VEGETATION.

The vegetation of the United States may be broadly divided into forest, grassland, and desert shrub.

The forest vegetation forms two broad belts, one extending inland from the Atlantic Ocean and the other inland from the Pacific Ocean. The eastern is relatively continuous, while the western is broken by many interspersed areas of nonforested land. In the region east of the Cascade-Sierra the forests are confined largely to mountain tops and high plateaus. The eastern portion of the western forest extends down over the Rocky Mountain range and divides the unforested portion of the United States into two broad strips, one of which lies east of the Rocky Mountains and the other between the Rockies and the Cascade-Sierra. Of these two belts the eastern constitutes the great grassland area, while the western constitutes the desert-shrub area. The desert area broadens out toward the south, and along the Mexican boundary forms a continuous strip extending from the Pacific Ocean to the Gulf of Mexico, interrupted only here and there at higher elevations.

NATURAL VEGETATION

ORIGINAL AREAS OF THE MAJOR DIVISIONS



TOTAL AREA OF THE UNITED STATES

1903 MILLION ACRES

Figure 1.—The relative original areas of major divisions of vegetation in the United States.

FORESTS.

The forests of the United States include a variety of economically useful timber trees hardly equaled anywhere in the world. In the Tropics the forests are richer in species; in Russia there are larger areas of contiguous forests; but nowhere else can one find such a vast area of forests combined with such a large number of species. Leaving out of consideration species of limited distribution, such as those of semitropical origin found along the coast in southern Florida and those which overlap from the Mexican flora, as well as all species which do not exceed 1 foot in diameter, 700 or more arborescent species are known to occur within the limits of the United States. Of these, not less than 100 species are of recognized economic value and about 200 species may be considered in forest management.

The forests of the United States are divided into the Eastern or Atlantic and the Western or Pacific, which are effectually separated in the central part of the continent by grassland that acts as a barrier between the species of the two regions even more effectively than a body of water of the same extent. In the British possessions, north of the fiftieth degree of latitude, the two forest divisions come together in one great stretch of continuous subarctic forests, extending from the Atlantic to the Pacific. In the south the forests of the eastern and western regions are also united by a narrow strip of forest peculiar to the plateau of northern Mexico and possessing features common to both regions.

The Eastern forest is essentially broad-leaved in composition and of unbroken distribution, covering both valleys and mountains, while the Western forest, which is distinctly coniferous in character, is characterized by abrupt changes in type, and is interrupted by treeless valleys. Excluding tropical species, the Eastern forest has 200 species of broad-leaved trees, many of which cover large areas and are of immense value, while the Western forest has only about 100 broad-leaved species, few of which are of any considerable value. On the other hand, the Western forest has 65 species of conifers and the Eastern but 29. It is interesting to note that only a few species (*Abies balsamea*, *Picea canadensis*, *Picea mariana*, *Larix laricina*) are common to both regions.

The Eastern forest was formerly unbroken and comprised more than 1,000,000 square miles. Although an estimate of the present area of the Eastern forest can only be approximate, it may be said with some certainty that out of the original seemingly boundless supply there is left now, after a little more than 100 years of settlement, not more than 260,000 square miles of merchantable forest lands, about 500,000 square miles having been cleared for farm lands and settlements, and the remainder culled of its valuable timber, devastated by fire, or turned into almost useless brush land.

The further division of the 260,000 square miles of merchantable timber east of the one hundredth meridian falls into about 130,000 square miles predominantly of conifers and 130,000 square miles predominantly of broad-leaved trees. The Northeastern States have about 20,000 square miles, the Lake States 20,000 square miles, and the Southern States about 90,000 square miles of coniferous forests.

The Western forest still corresponds largely with its original natural limits, although large areas have already been made unproductive by unrestricted lumbering and by destructive fires which have swept over enormous areas. It now includes about 130,000 square miles of merchantable forest, of which about 65,000 square miles lie in the Cascade-Sierra and Coast Ranges in the States of Washington, Oregon, and California, and about the same amount in the Rocky Mountains.

The forests of the United States, therefore, are very unevenly distributed over the continent. Two-thirds of the forest is concentrated in the eastern part of the continent, while the remainder is found on the western side and is mostly coextensive with the Rockies and the Cascade-Sierra and Coast ranges.

The causes which have influenced the present position and density of the large bodies of forests must primarily be sought in the peculiar distribution of rainfall in this country. The region occupied by the Eastern forest is unbroken by any great mountain ranges, except in the Appalachian system, and is mainly composed of rolling country with good soil conditions. The moisture-laden winds from the Gulf of Mexico sweep inland to a great distance, the precipitation being heaviest during the growing period of the summer. The favorable distribution of rainfall, together with favorable temperature and good soil conditions, enables the hardwoods to reach their greatest development in this region and excludes the conifers almost entirely, or relegates them to sandy plains and benches, rocky slopes, inclement altitudes, and cold swamps. The low, rolling character of the region of Eastern forest and the fact that the prevailing winds in the growing season are from the south, southwest, and southeast, allows the rainfall and consequently the forest to be distributed much farther inland than on the western front of the continent. In the central portion of the continent, however, far from the moist ocean winds, the moisture is insufficient to support a dense forest, and grassland vegetation becomes dominant, the natural forest being found chiefly along watercourses. The fact, however, that the rainfall in the eastern portion of the prairie region is still sufficient to insure the growth of a heavy forest leads to the inference that it is not low precipitation which has prevented the growth of trees. The flatness of the prairies, the absence of a clearly developed drain-

Figure 2.—Distribution of the main types of natural vegetation in the United States. The three major natural divisions of vegetation in the United States are forest, grassland, and desert shrub. The forest falls into two clearly defined regions, western and eastern. The western region comprises seven large forest subdivisions and two subdivisions of woodland. The eastern region comprises nine forest subdivisions. Within each of these large natural subdivisions there are many smaller distinct types not indicated on the map. Four-fifths of the forest was originally in the east. Of this original forest there remains now only about 10 per cent in virgin condition, 50 per cent having been cleared for farm land, 30 per cent cut over and now grown up to trees of sufficient size for saw logs or cordwood, and about 10 per cent cut over or devastated by fire and reduced to brushland. The western forest is about equally divided between the Rocky Mountains and the Cascade, Sierra Nevada, and Coast Ranges, and still includes nearly all its original area. The grassland vegetation falls into seven subdivisions and the desert shrub into three. About 70 per cent of the grassland east of the one hundredth meridian is now under cultivation, but in the west only about 10 per cent is under cultivation. Of the desert-shrub area about 2 per cent is under irrigation. The map indicates the great diversity of vegetation, as well as the value of the natural vegetation of the country. A comparison of this map with that of acreage of all crops (fig. 4) indicates also the agricultural potentialities of the remaining uncultivated land. The profile is a cross section along the thirty-ninth parallel and shows the variation of vegetation with altitude and distance from the ocean, and direction of slope.

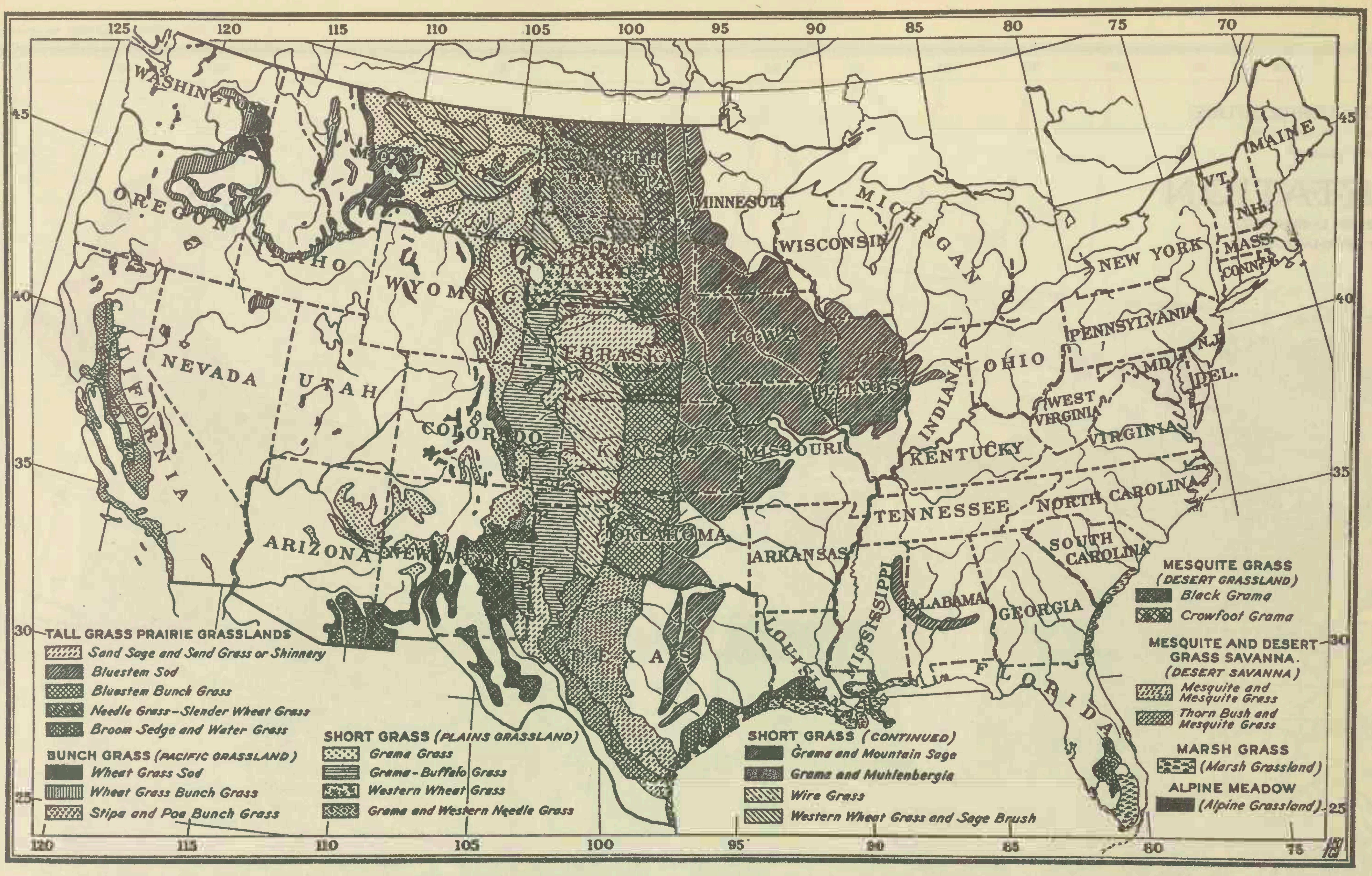
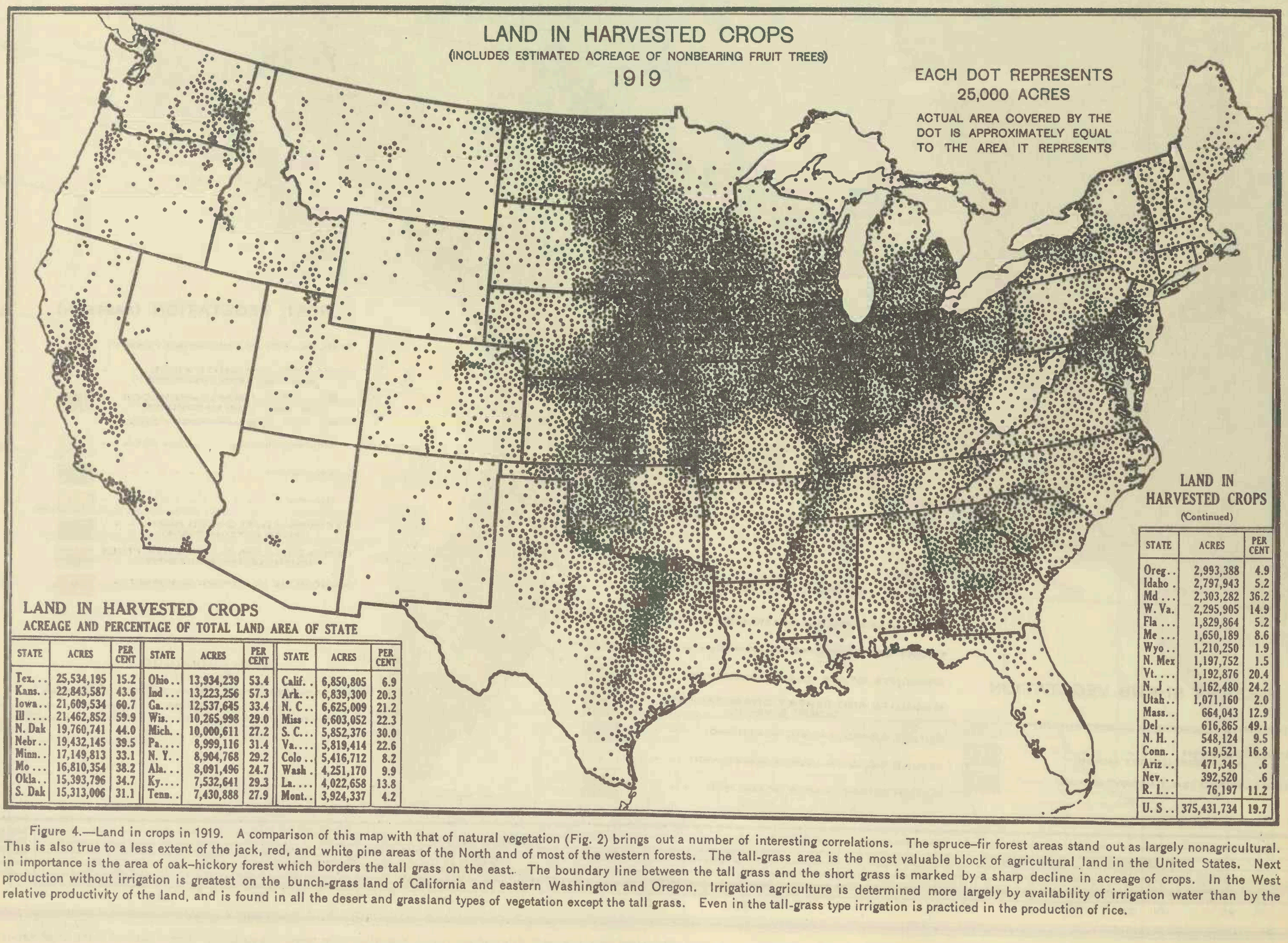


Figure 3.—Each of the five main grassland divisions, (1) the tall grass (prairie grassland), (2) the short grass (plains grassland), (3) the bunch grass (Pacific grassland), (4) the mesquite grass (desert grassland), and (5) the mesquite and desert-grass savanna (desert savanna), occupy large areas of land and consequently show many variations. The tall-grass vegetation may be subdivided on the basis of the dominant species into a number of types, the approximate distribution of which is shown on the map. The short-grass vegetation is similarly subdivided into types, eight of which are indicated on the map. In the bunch-grass vegetation three divisions are shown, two divisions in the mesquite grass, also two divisions in the mesquite and desert-grass savanna. The subdivisions not shown occupy small or restricted areas scattered throughout the main divisions, and the distribution can not be shown on a small-scale map.



LAND IN HARVESTED CROPS

ACREAGE AND PERCENTAGE OF TOTAL LAND AREA OF STATE

STATE	ACRES	PER CENT	STATE	ACRES	PER CENT	STATE	ACRES	PER CENT
Tex. . .	25,534,195	15.2	Ohio . .	13,934,239	53.4	Calif. .	6,850,805	6.9
Kans. .	22,843,587	43.6	Ind . . .	13,223,256	57.3	Ark. . .	6,839,300	20.3
Iowa . .	21,609,534	60.7	Ga. . . .	12,537,645	33.4	N. C . .	6,625,009	21.2
Ill	21,462,852	59.9	Wis. . .	10,265,998	29.0	Miss . .	6,603,052	22.3
N. Dak	19,760,741	44.0	Mich. .	10,000,611	27.2	S. C. . .	5,852,376	30.0
Nebr . .	19,432,145	39.5	Pa. . . .	8,999,116	31.4	Va. . . .	5,819,414	22.6
Minn. .	17,149,813	33.1	N. Y. .	8,904,768	29.2	Colo . .	5,416,712	8.2
Mo . . .	16,810,354	38.2	Ala. . .	8,091,496	24.7	Wash .	4,251,170	9.9
Okla. .	15,393,796	34.7	Ky. . . .	7,532,641	29.3	La. . . .	4,022,658	13.8
S. Dak	15,313,006	31.1	Tenn. .	7,430,888	27.9	Mont. .	3,924,337	4.2

LAND IN HARVESTED CROPS

(Continued)

STATE	ACRES	PER CENT
Oreg . .	2,993,388	4.9
Idaho .	2,797,943	5.2
Md . . .	2,303,282	36.2
W. Va.	2,295,905	14.9
Fla . . .	1,829,864	5.2
Me . . .	1,650,189	8.6
Wyo . .	1,210,250	1.9
N. Mex	1,197,752	1.5
Vt. . . .	1,192,876	20.4
N. J . .	1,162,480	24.2
Utah . .	1,071,160	2.0
Mass. .	664,043	12.9
Del . . .	616,865	49.1
N. H. .	548,124	9.5
Conn. .	519,521	16.8
Ariz . .	471,345	.6
Nev. . .	392,520	.6
R. I. . .	76,197	11.2
U. S . .	375,431,734	19.7

Figure 4.—Land in crops in 1919. A comparison of this map with that of natural vegetation (Fig. 2) brings out a number of interesting correlations. The spruce–fir forest areas stand out as largely nonagricultural. This is also true to a less extent of the jack, red, and white pine areas of the North and of most of the western forests. The tall-grass area is the most valuable block of agricultural land in the United States. Next in importance is the area of oak–hickory forest which borders the tall grass on the east. The boundary line between the tall grass and the short grass is marked by a sharp decline in acreage of crops. In the West production without irrigation is greatest on the bunch-grass land of California and eastern Washington and Oregon. Irrigation agriculture is determined more largely by availability of irrigation water than by the relative productivity of the land, and is found in all the desert and grassland types of vegetation except the tall grass. Even in the tall-grass type irrigation is practiced in the production of rice.

age, and poor soil drainage of the wetter portion are, in large part, responsible for their treeless condition. Repeated fires undoubtedly pushed the forest back and extended its boundaries farther eastward. Forests have begun to work westward since the settlement of the prairies has broken up the virgin sod and prevented to a great extent the occurrence of prairie fires. West of the prairies lie the plains, which have always separated the two great forest regions, since the moisture is insufficient to develop forest growth.

Figure 5.—An open oak stand (Chaparral) merging with California grassland. It is characteristic of most of the foothills and interior valleys of California and is found also in Arizona. Sequoia National Forest, Tulare County, Calif. Photographed by Alfred Gaskill.

The western coast forest is an excellent example of the effect which rainfall, here almost entirely of the cyclonic type, combined with topography, altitude, and temperature, has upon the forest. Nearly the entire region is mountainous, with a steep and high coast range almost at the water's edge. The prevailing winds are westerly and northwesterly, but the chief rain-bearing winds are southeasterly, southerly, and southwesterly, under the influence of passing cyclones, which are most frequent in winter and cause the strongest winds and heaviest rainfall in that season. Moisture thus brought in from the relatively warm ocean far to the south and southwest yields in the north over both mountains and valleys, and in the south principally over the mountains, low-hanging clouds, and much rain. Precipitation is heaviest in the northern part of the area, where cyclonic centers pass more frequently than in the south, and heaviest on the western flanks of the ranges, where the air is forced to rise over the mountains and to drop its excess moisture because of the expansional cooling resulting from its ascent. The eastern slopes are comparatively dry because the air is there descending. Such moisture as passes over one range unprecipitated helps to cause rain on the range next to the east if the ascent there is great enough.

Summer conditions are radically different, especially in the southern part of the area. The prevailing wind on the coast is westerly and northwesterly, and, coming from the relatively cool waters of more northern latitudes, brings only moisture enough to cause a belt of frequent fog and cloud limited almost entirely to

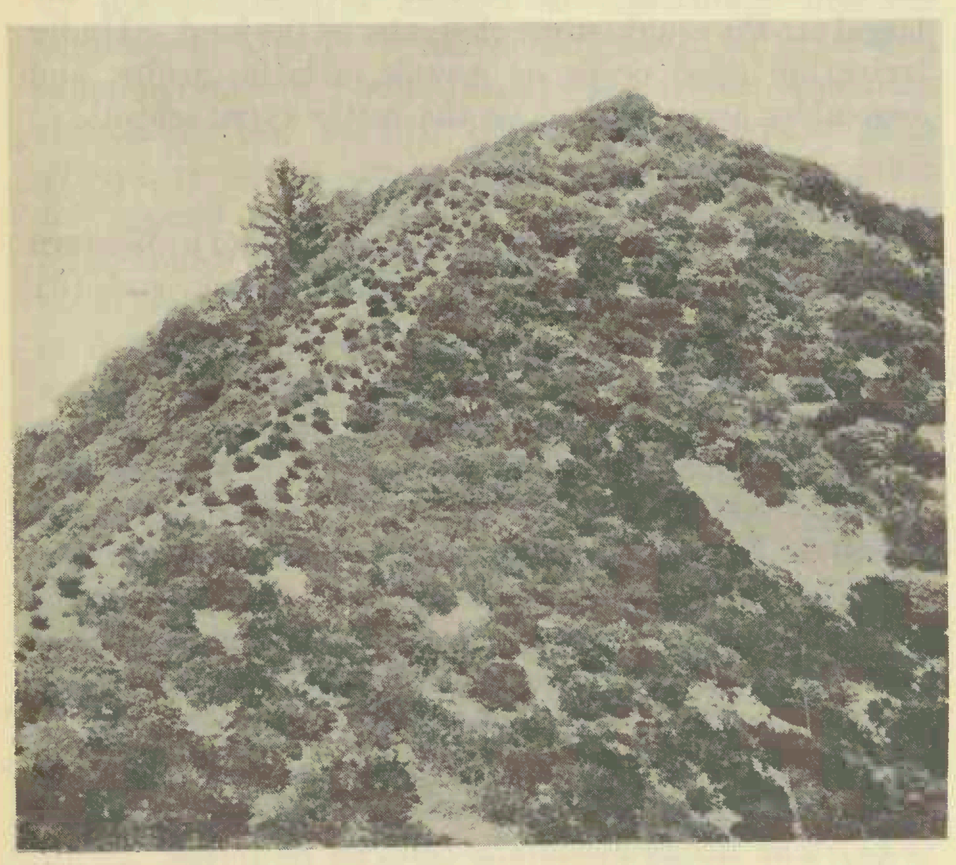


Figure 6.—Chaparral composed principally of small-sized oak, ceanothus, and manzanita, characteristic of the foothills of southern California. It ranges from an impenetrable thicket of low shrubs to open oak stands. A fire line in the center. Southern California. Photographed by E. A. Sterling.

the ocean slopes of the coast ranges. Summer cyclones, comparatively weak and few in number, bring a little rain to the outer coast in the north. In the south, where such cyclones are rare and rain is rarer still, the prevailing onshore winds are thoroughly "dried" over the sunny land, especially in the valleys, while an occasional hot wind from the continental interior still further emphasizes the dryness of the summer season. Thus the region is one of winter rains and summer droughts, except along the northern coast.

This combination of wet winters and dry summers determines the location and character of the forests. On the lowlands and valleys of the south the hot summers and the scant winter rainfall make forest growth impossible, leaving the land either to grasses or to desert shrubs which can adapt themselves to semiarid conditions. The mountains, having a precipitation that is greater and of longer duration, with much less evaporation, furnish better growing conditions, and usually are forested. Growth is in proportion to the altitude up to an elevation of from 8,000 to 9,000 feet. Above this, the winds and the severity of the winter, and possibly the decrease of precipitation, make conditions adverse to dense forests, the timber line occurring usually at about 10,000 feet.

It is a noticeable fact that nearly all the principal mountain ranges have their heavy timber on the slopes exposed to the prevailing wet winds, while the opposite sides are usually only scantily clothed with timber. This is most strikingly shown in the Sierra Nevada. The rain-bearing winds, striking the westerly slopes, precipitate a part of their moisture before they cross the summit. Thence as they travel downward and become heated they cease to precipitate and even absorb what little moisture there may be on these slopes. As a result, the eastern slopes are in general very different in character from the western, the latter receiving enough rain and snow to support a strip of magnificent forest. In western Washington and Oregon, on the other hand, and along the northern half of the California coast, the rainfall in winter and the fog and cloud in summer are unusually heavy, and as a result the forest growth is very dense, particularly in the redwood belt of California.

The Rocky Mountain region, being nearer the interior, receives less rain and snow than the Coast mountains and the Sierra Nevada, and the forest has a severer struggle with the elements. In the northern portions the forest is dense and well developed, but in general, as a result of unfavorable condition of growth, it is broken up into smaller areas and is more open than the typical Pacific coast forest. The southern Rockies derive much of their scanty moisture from the Gulf of Mexico.

Since hardwoods require for their development a high humidity and rainfall, especially in the growing season, they are largely absent from the western forest. The long, dry summer seasons of the western part of the continent prevent their development and yield the land to more hardy conifers. In the wet coast country the hardwood growth is more thrifty, and many species, such as maple, elder, oak, ash, and chinquapin, reach merchantable size; but, in comparison with the magnificent coniferous growth, they constitute an insignificant part of the forest.

GRASSLAND.

Lying between the western and eastern forest belts, and extending from Canada on the north to Mexico on the south, is the great grassland area, broken only by river courses and occasional buttes or low mountains.

Grasslands characterize areas in which trees have failed to develop, either because of unfavorable soil conditions, poor drainage and aeration, intense cold and wind, deficient moisture supply, or repeated fires Grasses of one kind or another are admirably suited to withstand conditions of excess moisture, excess drought, and fires which would destroy tree growth.

Grasslands usually are well supplied with water in the surface soil during the growth period and do not depend to any extent upon deeply stored soil moisture. In fact, water in the deeper soil usually enables taller-growing plants, such as shrubs or trees, to replace the grasses. Grasses are, therefore, characteristic of regions of summer rainfall. A great profusion of showy flowering plants are usually found within the grasslands, and they often present a varied appearance during the early part of the season, due to plants which later play no very important part in characterizing the areas.

DESERT SHRUB.

Between the Rocky Mountains on the east and the Cascade-Sierra on the west, and extending from the Canadian to the Mexican boundary, lies the great inland desert, characterized largely by xerophytic shrubs. The deserts occupy the Great Basin, except for isolated mountain forests, most of the drainage basins of the Columbia, the Snake, the Colorado, and the Rio Grande, and small areas east of the Rockies drained by the Big Horn, Platte, and Arkansas rivers. In the south, near the Mexican boundary, the desert broadens out, reaching from the Pacific nearly to the Gulf of Mexico. It is interrupted here and there by intrusions of grasslands or at higher elevations by forests. This whole area is characterized by a deficient rainfall and an excessive evaporation rate. The perennial vegetation which gives character to the deserts consists principally of shrubs. In the south succulent plants become more important. The relatively small size of the plants, together with their small leaves well protected against excessive transpiration, the small amount of growth produced each year, and the wide spacing enable these plants to conserve the scanty moisture supply and continue their growth during the long rainless periods. Such dry periods may occur at any time of the year. The loss of moisture from desert or dry-land soils is almost entirely due to plant transpiration. A relatively small quantity is lost from the surface of the bare ground between the plants, except surface water immediately following rains. Wide spacing is, therefore, one of the most effective means of conserving a scant moisture supply.

DETAILED DESCRIPTION OF THE FOREST VEGETATION.

THE WESTERN FOREST REGION.

The western forests, with all their variety of species, their physiographic and climatic differences, can be classified into two units of woodland and three large

Figure 7.—Piñon and one-seeded juniper forest. (Piñon–juniper). Characteristically open. The lowest belt of forest in most of the southwestern part of the United States. Santa Fe, N. Mex. All photographs not otherwise acknowledged were taken by H. L. Shantz.

natural units of timberland. The woodland divisions are:

- Chaparral, or southwestern broad-leaved woodland.
- Piñon–juniper (*Pinus–Juniperus*), or southwestern coniferous woodland.

The timberland divisions are:

- Western yellow pine–Douglas fir (*Pinus–Pseudotsuga*), or western pine forest.
- Cedar–Hemlock (*Thuja–Tsuga*), or northwestern coniferous forest.
- Spruce–fir (*Picea–Abies*), or northern coniferous forest.

These divisions correspond mainly to distinct regions, yet different divisions, often several of them, may occur within the same region but on different slopes or at different altitudes. Each is practically always associated with a distinct climatic belt. The description of these main divisions of forest vegetation begins with the belt which altitudinally is the lowest and therefore the driest. Each successive altitudinal belt corresponds to a moister and cooler climate. This is true of all the five divisions, with the ex-

Figure 8.—Pure western yellow pine forest. (Yellow pine–Douglas fir.) An open stand, usually with grass underneath, affording good grazing; the most extensive and commercially the most important type of the yellow pine–Douglas fir forests. Compare this forest with Figure 22, the southeastern pine forest. Coconino National Forest, Ariz. Photographed by A. G. Varela.

Figure 9.—Typical lodgepole pine forest. (Yellow pine–Douglas fir.) Characteristic dense stand. It comes in, as a rule, as a result of fires in Douglas fir and Engelmann spruce forests. Big Horn County, Wyo. Photographed by E. M. Griffith.

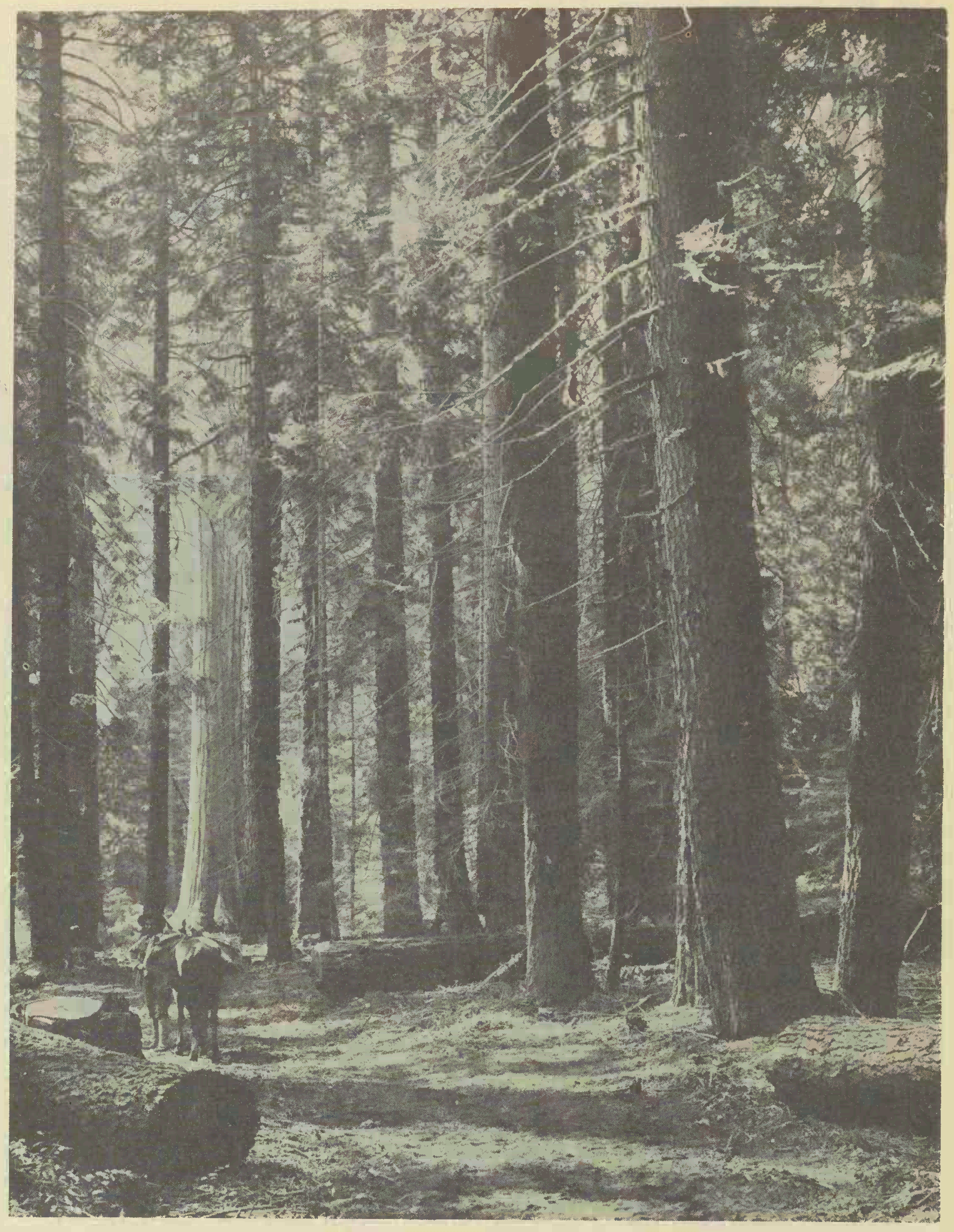


Figure 10.—Mixed forest of sugar pine, yellow pine, incense cedar, and white fir. (Yellow pine–Douglas fir.) A sequoia in the background; typical of the west slope of the Sierras, best developed yellow pine found in this type; also sugar pine and incense cedar. Most favorable climatic conditions for the growth of yellow pine. Sequoia National Park, Calif. Photographed by Alfred Gaskill.

ception of the cedar–hemlock division, which is confined to a distinct geographic region, namely, the Pacific Northwest.

WOODLAND.

The woodland, as has been noted, has two divisions, the chaparral and the piñon–juniper.

Chaparral. (Figs. 5 and 6.)

Chaparral is a mixed forest of stunted hardwood trees and shrubs. It occupies a belt below the yellow pine and above the desert shrub. Although this type of forest vegetation occurs throughout most of the foothills of the central and southern Rockies and the mountains of Arizona, Nevada, Utah, and California, it is most typical of southern Arizona and southern California. The chaparral belt sometimes alternates in the Rockies with the piñon–juniper belt, and often it forms a distinct fringe along the upper edge of the sagebrush belt. In southern California the chaparral belt occupies an area of about 5½ million acres. In some places in southern California chaparral extends to sea level and in others it reaches an altitude of 8,000 feet. There are about 116 different species which make up the chaparral belt, the bulk of which are found at elevations from sea level to about 5,000 feet.

The species composing the chaparral vary in the different regions. Thus, in the Rockies chaparral is mainly of scrub oak (*Quercus gambelii*) or mountain mahogany (*Cercocarpus parvifolius*) or juneberry (*Amelanchier*).

In southern California the following are the most important species:

Highland live oak (*Quercus wislizeni*), scrub oak (*Quercus dumosa*), holly-leaf cherry (*Prunus ilicifolia*), sumac (*Rhus laurina*), wild lilac (*Ceanothus hirsutus*), and manzanita (*Arctostaphylos glauca*).

The chaparral areas of southern Arizona are open groves of oak scattered over the desert grassland. In the lower belt of the interior valley of California a similar open oak type of savanna occurs on the foothills above the weed grass. Above the oak zone the dense shrub cover of manzanita, wild lilac, and oak brush form a broad belt below the coniferous forest. Nearer the ocean immense tracts are covered by a pure stand of *Adenostoma fasciculata*, which is the most important plant of the lower shrub types of chaparral along the Pacific coast of southern California. It occurs for the most part just above the southern desert shrub and below the oak-brush type of chaparral. It occurs most abundantly near the ocean, where, although subjected to extended periods of drought, it is never subjected to the extreme heat or dry air which is characteristic of the southern desert shrub.

The chief economic importance of chaparral lies in its watershed protection. The climatic conditions are similar to those of the piñon–juniper belt.

The chaparral, especially in southern California and Arizona, occurs on dry mountains which are ill-adapted to agricultural development. Citrus fruits are grown in so far as possible only in the relatively frost-free zone which occupies the low bench lands. The hilly land, because of its steeply rolling surface and its inaccessibility to irrigation water, has not been developed.

Piñon–Juniper. (Fig. 7.)

The piñon–juniper division forms a distinct woodland belt which, like the chaparral, is just below the yellow-pine zone. This belt is to portions of western Texas, to the foothills of the southern Rockies and of the mountains of Arizona and Nevada, and to the eastern slope of the Sierras, what chaparral is to the foothills of southern Arizona and southern California. In places it intermixes with the chaparral. Only a few areas of piñon-juniper are found north of latitude 44°. The principal species of juniper are the Rocky Mountain red cedar (*J. scopulorum*), Utah juniper (*J. utahensis*), the one-seeded juniper (*J. monosperma*), and alligator juniper (*Juniperus pachyphloea*), while piñon is represented by two species of piñon (*Pinus edulis* and *P. monophylla*). At the upper part of this belt piñon preponderates, while juniper is a little more abundant in the lower portions. It is often found mixed with western yellow pine and occasionally with stunted Douglas fir (*Pseudotsuga taxifolia*) at higher altitudes, and with so-called scrub oaks (*Quercus gambelii* and *Q. undulata*). In the south it occurs with a number of other small oaks and hardwoods, together with Mexican piñon (*Pinus cembroides*), Arizona cypress (*Cupressus arizonica*), and junipers. Over thousands of square miles piñon–juniper and sagebrush alternate, the former occupying rough broken country or shallow stony soil, while sagebrush occurs on the more level ground, which has a deep, uniform soil.

The area of land occupied by piñon–juniper, especially in the Great Basin, is very great. Economically these trees are important, since they form the chief source of timber for mine props, fence posts, and fuel for local use. The juniper–piñon belt is characterized by rather hot, dry summers, the annual rainfall being less than 20 inches. The moisture supply is inadequate for any save dry-land agricultural methods. The actual production of crops within this area is small, due largely to the rough, stony character of the land. Under irrigation good crops of cereals, alfalfa, fruits, and vegetables are produced on the better types of soil.

TIMBERLAND.

The timberland has three divisions: (1) Western yellow pine–Douglas fir, (2) cedar–hemlock, and (3) spruce–fir.

The Western Yellow Pine-Douglas Fir Forest.

This division of the timberland includes:

(*a*) The pure forest of western yellow pine of Arizona, New Mexico, southern Utah, the Black Hills of South Dakota, the eastern slope of the Cascades and the Sierras and the Columbia Basin, as well as the yellow pine stands throughout the central and southern Rocky Mountains, western Montana, western Idaho, and eastern Oregon (Blue Mountains).

(*b*) The western yellow pine–sugar pine–incense cedar forest of the Sierras in California.

(*c*) The Rocky Mountain Douglas fir forest.

To these may be added two other types of forest of a more temporary character which, if left undisturbed for a long period, would gradually give way to other types, namely, (*d*) the lodgepole pine (*Pinus contorta*) forests of Montana, Wyoming, and Colorado; and (*e*) the western larch–Douglas fir forests of northwestern Montana and northern Idaho.

It may seem at first too far fetched to include in the western yellow pine–Douglas fir division such apparently widely differing stands. Yet if we analyze the biological peculiarities of the species which make up these stands, their habitats, and trace their life histories after severe burns and logging, it becomes clear that a large number of the lodgepole pine stands in northern Wyoming and throughout the central Rocky Mountains, the western yellow pine–western larch–Douglas fir stands of northwestern Montana and northern Idaho, the sugar pine–incense cedar–western yellow pine forests on the west slope of the Sierras, and the Jeffrey pine forest mixed with white fir (*Abies concolor*) on the east slope, the pure forests of western yellow pine on the east slope of the Cascades, as well as those of Arizona, of the Black Hills and of northern Nebraska, all grow under more or less similar climatic conditions and occupy, as a rule, southern slopes or otherwise dry situations. At the two extreme ends of

the range of conditions peculiar to these forest units there may be found species which are also dissimilar in their climatic requirements. Thus, for instance, sugar pine (*Pinus lambertiana*), which is such a prominent component species of the sugar pine–yellow pine–incense cedar forests of California, will not grow in the dry, pure forests of yellow pine in Arizona, but on all intermediate situations all the species may be found growing together and are interchangeable one with another.

All these forests, although apparently different in character, in reality partake of the same biological characteristics and have more or less similar conditions of growth, as do the two principal species which give character to these different forests, namely, western yellow pine and Douglas fir.

Pure yellow pine forest (fig. 8).—Of the three great types of forests which make up the western yellow pine–Douglas fir division, the pure forests of yellow pine are by far the most extensive and economically most important. They occur on dry, hot slopes or flats, mainly at low elevations from 3,500 to 4,500 feet, on the west slope of the Sierras, and on the east slope they occupy the entire timbered slopes, and consist largely of Jeffrey pine (*Pinus jeffreyi*), western yellow pine, and white fir. Pure yellow pine forests constitute by far the greater part of the forests containing most of the merchantable timber in Arizona and New Mexico. In the southern part of each of these States the belt lies between about 6,000 and 7,500 feet. At its upper edge Douglas fir and Engelmann spruce come in, and at about 9,000 feet dominate the stand. In the northern part of New Mexico these forests are nearly 1,000 feet higher. The curious fact that these forests occur at lower elevations in the southern part of the State of New Mexico is in some way connected with the level of the adjacent plains. Pure western yellow pine stands also occur in northern Nebraska at an elevation of 3,000 feet, and in the Black Hills at from 3,000 to 5,000 feet; also on south slopes and at all lower altitudes in eastern Washington, Oregon, and central Idaho between 2,500 and 4,500 feet, and in northwestern Montana and northern Idaho at the lower altitudes on warm, sunny exposures, low ridges, and rather dry benches and gravelly flats. The pure yellow pine forest, except in Washington, Idaho, Montana, Nebraska, and the Black Hills, occupies a belt that lies between the piñon-juniper woodland or chaparral below and Douglas fir or lodgepole pine above. It lies almost wholly within the "transition zone" as defined by biologists. It is not continuous, but often includes open grazing lands that give a parklike effect to the region. This effect is heightened by the comparative absence of underbrush and the presence of a more or less dense growth of grass and other herbaceous plants beneath the trees. The trees themselves are usually large, mature, growing in groups, or widely spaced, so that the sunlight reaches the ground in all parts of the forest with but little interference by the crowns. The typical forest litter of leaves, twigs, decaying stems, and branches is absent or found in small quantities near the base of the trees, and in many regions the only litter beneath the trees is a pile of dry cones, the accumulation of a number of seed years. These typical western yellow pine forests much resemble the open longleaf pine forests of the southeast and may, where the surface is not too rocky, be as easily traveled.

A forest fire or logging, as a rule, will not change the character of the forest; in other words, its natural cycle is western yellow pine following western yellow pine. Occasionally, however, after very severe fires, particularly at the upper and lower extension of the forest, the type of vegetation above or below may temporarily encroach on the burned or logged-off yellow pine forest. The alternation of aspen (*Populus tremuloides*) and pine in the Black Hills of South Dakota and of chaparral and pine in the southwest are good examples of such sequences of growth.

The climate of pure western yellow pine forests is that characteristic of hot and dry interior plateaus and mountains. This applies particularly to the Rocky Mountain form, which occurs in the central and southern Rockies, and occupies generally drier sites than the true *Pinus ponderosa*. Most of the area has a rainfall of from 20 to 30 inches. The forests occur in situations where the mean annual temperature ranges as low as 40° F., and the mean temperatures during the growing season from about 50° to 60° F. Maximum temperatures of 110° F. are not uncommon. The trees withstand winter temperatures as low as —30° F.

The land occupied by this forest has not been extensively used for agricultural purposes, as it lies at a rather high elevation and is characterized for the greater part by a short growing season. It occupies also uneven and stony soils. It is suitable, however, for crops adapted to cool weather and short seasons. The open parks in the pure yellow pine forests within Arizona and New Mexico offer the best "dry farming" possibilites in these States, though but little of the land is in cultivation when one considers it in relation to the entire area of yellow pine forests. Oats, barley, wheat and rye are the principal cereals, while potatoes and alfalfa are grown to a limited extent. Vegetables also can be grown within this area, although the total crop production on land occupied by western yellow pine is relatively small. Because of the open character of the forests and the grassy cover, this land is especially adapted to grazing.

The yellow pine–sugar pine–incense cedar forest (fig. 10).—Next in importance are the mixed stands, chiefly of sugar pine, western yellow pine, white fir, Douglas fir, and incense cedar (*Libocedrus decurrens*). This forest is confined largely to the west slopes of the Sierras and to the Coast Range in California, and presents probably the most favorable climatic conditions of the western yellow pine–Douglas fir division. Still, the limits of precipitation and temperature are not unlike those of the pure yellow pine stands. The average temperature during the growing season for the region ranges between 44° and 60° F.; for pure yellow pine stands it is between 50° and 60°. The annual precipitation of 20 inches practically limits both the pure western yellow pine forests and the mixed yellow pine-sugar pine-incense cedar forest, although the best development of the latter takes place when the rainfall is considerably above 20 inches. This forest varies in composition according to altitude, soil, and exposure, so that there can be distinguished several fairly distinct types. Thus, on moderately dry western slopes, and especially on soils of serpentine formation on the western slope of the Sierras, the most prevalent type of forest is that of western yellow pine-incense cedar. Under the same conditions of temperature and soil, but at an elevation of 3,500 to 5,500 feet on the western slope of the Sierras, it is yellow pine–sugar pine. White fir plays a conspicuous part in all these types of forest, as well as in the pure yellow pine forests.

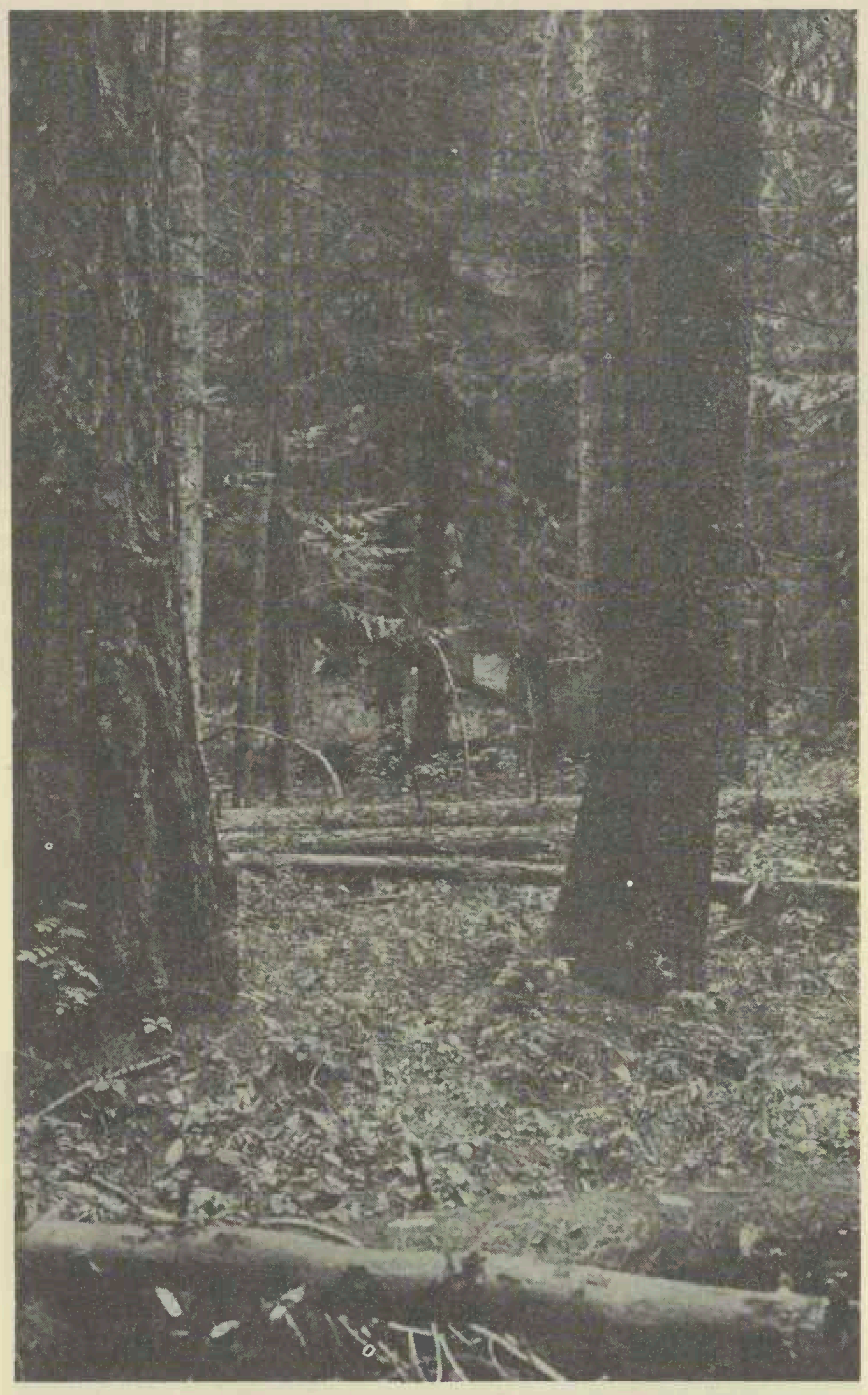


Figure 11.—Mixed forest—western larch and western white pine. (Cedar–hemlock.) The stand is about 140 years old. Western red cedar and hemlock are shown in the photograph to come in as an understory. Northwestern Idaho. Photographed by Austin Cary.

Agricultural development within the area has been limited largely by the unfavorable mountainous conditions of the land.

Rocky Mountain Douglas fir forest.[2]—Just above the yellow-pine belt there occur mixed stands of western yellow pine and Douglas fir. These are found in the central Rockies at elevations from 6,000 to 9,000 feet, chiefly on sandstone and granite soils; on the west slope of the Sierras on northwesterly slopes at elevations of from 4,500 to 5,500 feet; and in Arizona at elevations between 8,500 to 10,000 feet on the south slopes and between 7,500 feet and 9,000 feet on the north exposures. On cool northerly and northeasterly slopes, at altitudes of about 5,000 to 6,000 feet on the west slope of the Sierras and between 8,000 and 10,000 feet in the central Rockies, the mixed stands of yellow pine and Douglas fir become practically pure Douglas fir stands. Along the lower altitudinal limit of the lodgepole pine zone in the central Rockies, on south slopes and on dry rocky knolls, the Douglas fir mixes freely with lodgepole pine, giving rise to a mixed lodgepole pine–Douglas fir stand.

These several forest types, although distinct in composition and even in their altitudinal range, still belong to the western yellow pine–Douglas fir series. They are all characterized by the presence of Douglas fir as one of their principal species. Throughout the Rockies Douglas fir and western yellow pine alternate.

This forest belt receives slightly more precipitation than the pure western yellow pine belt. The annual precipitation in the Douglas fir zone in the Rockies is between 25 and 35 inches, largely in the form of snow. The summer and winter temperatures are, however, about the same as in the pure western yellow pine belt, and in general it is characterized by the same dryness of soil.

Lodgepole pine forest (fig. 9).—The lodgepole pine forests are chiefly characteristic of the Rocky Mountains, although they occur also in Idaho, Washington, Oregon, and California. In Colorado the best stands of lodgepole pine are usually found between 7,500 and 9,500 feet, in Wyoming between 7,000 and 9,000 feet, and in southwestern and central Montana between 6,000 and 8,500 feet. They occupy usually an altitudinal belt of from 2,000 to 2,500 feet in width. They often descend as low as 4,500 feet on northern exposures and go up as high as 11,500, as in Colorado, southern Wyoming, and California. This wide altitudinal range of lodgepole pine is due to the fact that it is a pioneer tree which invades ground left open by other species, chiefly as a result of fires. It occupies ground belonging both to Engelmann spruce and to Douglas fir. The present extensive lodgepole pine forests have undoubtedly been brought about to a large extent by burns which enabled the lodgepole pine to spread at the expense of Douglas fir and Engelmann spruce (*Picea engelmannii*). Lodgepole pine stands, therefore, occupy any intermediate zone on the line between the Douglas fir and spruce. They rarely go to the lowest and driest sites occupied by Douglas fir and only occasionally become alpine, generally at 8,000 to 11,000 feet in elevation. The lodgepole pine forests belong, therefore, to two divisions, the western yellow pine–Douglas fir and the spruce–fir. Those on the drier and southerly exposures and at altitudes below the natural altitudinal range of Engelmann spruce may be classed with the western yellow pine–Douglas fir forests. The bulk of the lodgepole pine forests must be placed in the western yellow pine–Douglas fir division, since they occur largely in the same climate as the western yellow pine and Douglas fir stands. Lodgepole pine forests occur where the annual average precipitation is 18 inches or more. The best developed stands occur where the precipitation exceeds 21 inches. This species endures for short periods extremes of temperature varying from approximately 100° F. to —55° F. The growing season in lodgepole pine areas is short. Killing frosts are likely to occur until about the middle of June, and the first autumn frost comes in late August or early in September. In their requirement for moisture and temperature, the lodgepole pine forests stand between Douglas fir, on the one hand, and Engelmann spruce and alpine fir (*Abies lasiocarpa*), on the other.

The lodgepole pine forests are economically the most important timber belts of that portion of the Rocky Mountains lying between northern Colorado and central Montana. They are the source of mine timbers, converter poles, railway ties for the transcontinental railroads, and of lumber to a small extent.

Western larch—Douglas fir forest.—In northwestern Montana and northern Idaho, on dry benches, as well as on southerly and southwesterly slopes, there occur mixed stands of western larch, Douglas fir, western yellow pine, and lodgepole pine. After burns, western larch occasionally forms practically pure stands, especially on fairly dry ridges and benches. On the more favorable sites it is gradually crowded out by the western white pine, which in turn is later replaced to a large extent by western red cedar, western hemlock, and lowland white fir. On the warmer southern slopes or the more shallow rocky soils Douglas fir and yellow pine enter in mixture with larch. On very dry, steep southern and southwestern slopes at lower altitudes the larch gives way entirely and western yellow pine forms pure forests.

Cedar-Hemlock Forest. (Figs. 11 and 12.)

This forest may be divided into two large units: (*a*) The western white pine and larch region of western Montana and northern Idaho, and (*b*) the Pacific Douglas fir of the western slope of the Cascades. These forests and the large number of minor forest types, although they differ in composition, have many

[2] Rocky Mountain Douglas fir is used not as a geographic term but to designate a form distinct from the Pacific Coast Douglas fir of Washington and Oregon.

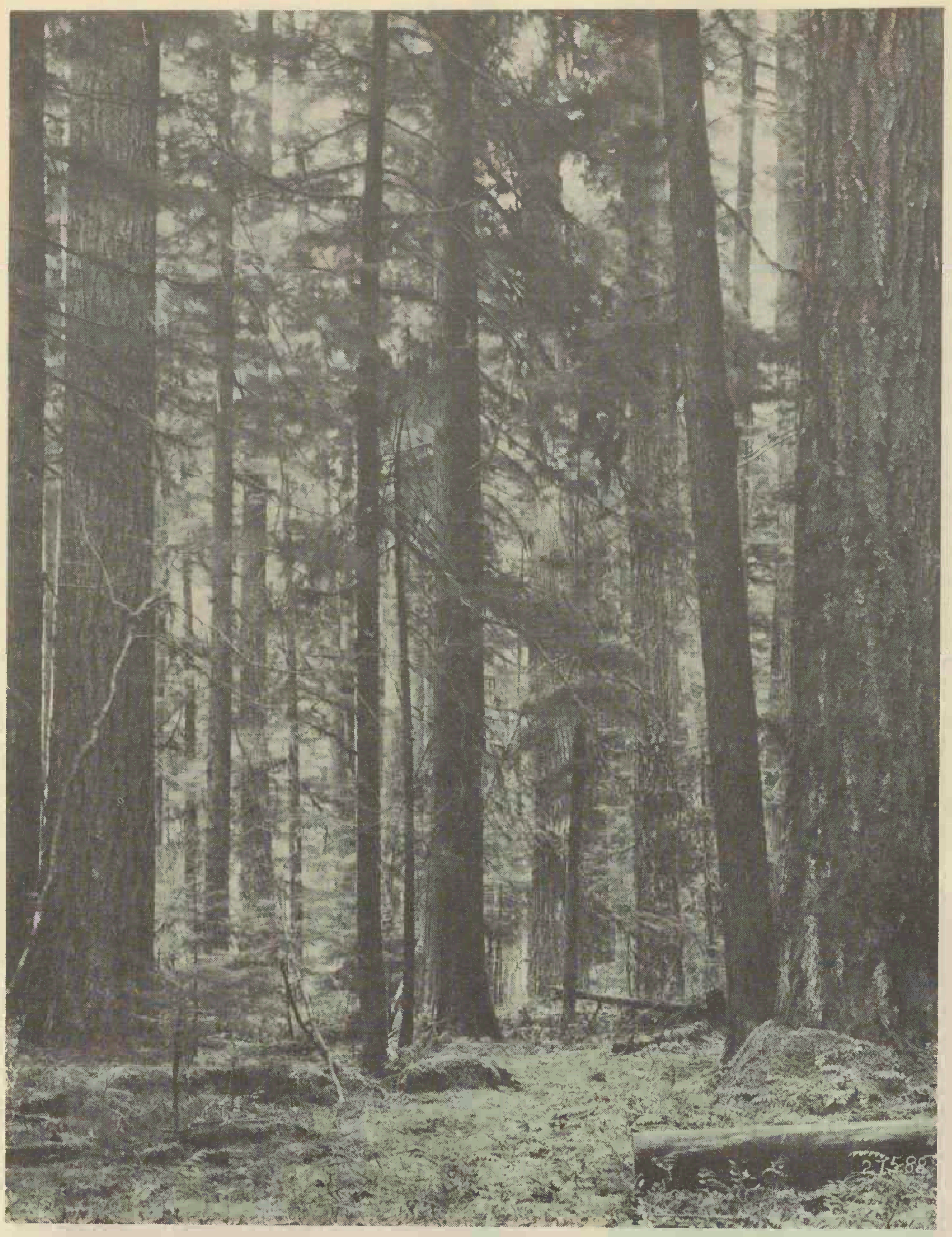


Figure 12.—Pacific Douglas fir forest. (Cedar–hemlock.) Western hemlock is shown in the photograph, entering as an understory. As a result of fires, the Douglas fir starts in pure stands. The hemlock begins to come in only after the ground is shaded and duff is accumulated on the ground. If left to itself the forest would gradually revert to hemlock. The present uniform Douglas fir stands are due to the large forest conflagrations of the past. Oregon. Photographed by F. G. Plummer.

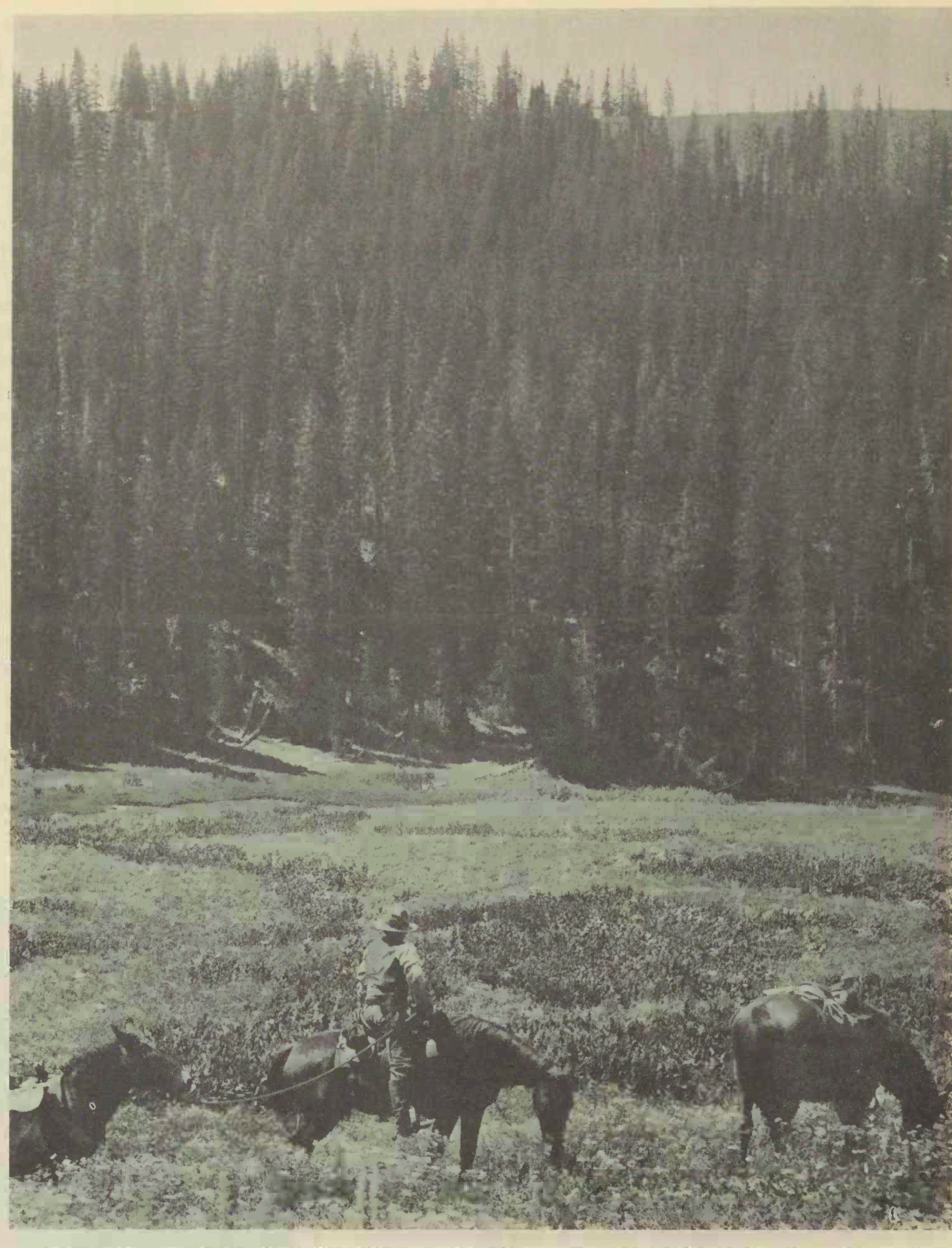


Figure 13. Engelmann spruce forest (Spruce–fir). The principal forest of high altitudes in the Rockies above lodgepole pine or Douglas fir forests. In the Cascades and Sierras true firs take its place, similar to the spruce–fir of the Northeast (see fig. 15.). Uinta Mountains, Utah. Photographed by Edw. J. Ludkin.

common traits and gravitate toward the same ultimate forest—the western red cedar and hemlock (*Thuja plicata* and *Tsuga heterophylla*).

Western white pine-western larch (fig. 11).—This region is confined chiefly to northern Idaho and adjacent portions of Montana and Washington. In the Coeur d'Alene Mountains, the Cabinet Mountains, the western spurs of the Bitterroots, and the south end of the Selkirks in Idaho, extreme western Montana, and extreme northeastern Washington, the western white-pine forests predominate. Pure stands are not common. Occasionally, as the result of the accident of seeding or because it is an especially favorable site, western white pine (*Pinus monticola*) will form 80 to 95 per cent of the stand. Altitudinally, 4,500 feet may be assumed as the upper limit for western white-pine forests.

The western red cedar, the western hemlock, and the lowland white fir form usually an undergrowth in a white-pine forest. The cedar and hemlock commonly predominate on the more moist sites and lowland white and alpine firs on the drier. In some forests toward the upper limit of western white pine, especially in northwestern Montana, hemlock, lowland white fir, and cedar are scarce or absent, and Engelmann spruce forms the ultimate type. A study of the life history of these stands has shown that often after a severe burn the first tree to occupy the ground suitable to western white pine is the western larch (*Larix occidentalis*), which comes in as the pioneer tree, shades the ground, and thus affords the protection necessary for the western white pine to establish itself. The western white pine, soon after it becomes established under the shade of the larch, begins to crowd the latter, overtops it, and gradually exterminates all but the most vigorous specimens. Under the shade of the western white pine, larch, and red cedar, hemlock and lowland white fir (*Abies grandis*) begin to come up, and these eventually crowd out the white pine and become practically the sole occupants of the ground. Stages in this development can be found throughout the western white-pine region.

An average annual precipitation of about 30 inches is characteristic of the western white pine region as a whole. The bulk of the precipitation throughout the western white-pine region comes during the autumn, winter, and spring. The summer is relatively dry. Within the western white-pine region the days when the humidity is less than 20 per cent are very few, the average humidity for the dry summer season usually ranging from 30 per cent in the drier regions to 60 per cent or more in the more moist. The mean annual temperature varies from 41° to 51° F., and the mean July and August temperatures from 50° to 68° F.

The Pacific Coast Douglas fir (fig. 12).—This region is marked by a number of distinct forest types which also gravitate toward a western red cedar–hemlock forest. Thus on low, moderately humid slopes, from sea level to 3,000 feet, there are found large stretches of pure Douglas fir. On exactly similar areas there occur mixed stands of Douglas fir–hemlock–cedar which are a further stage in the development of the pure Douglas fir. If it were not for the periodical occurrence of fires, the pure Douglas fir stands would give way to a forest in which western red cedar and hemlock would be the principal species. Both the western white-pine region and the Douglas fir region, although they have different starting points, in their ultimate development tend to become one type of forest and therefore biologically form virtually one large unit.

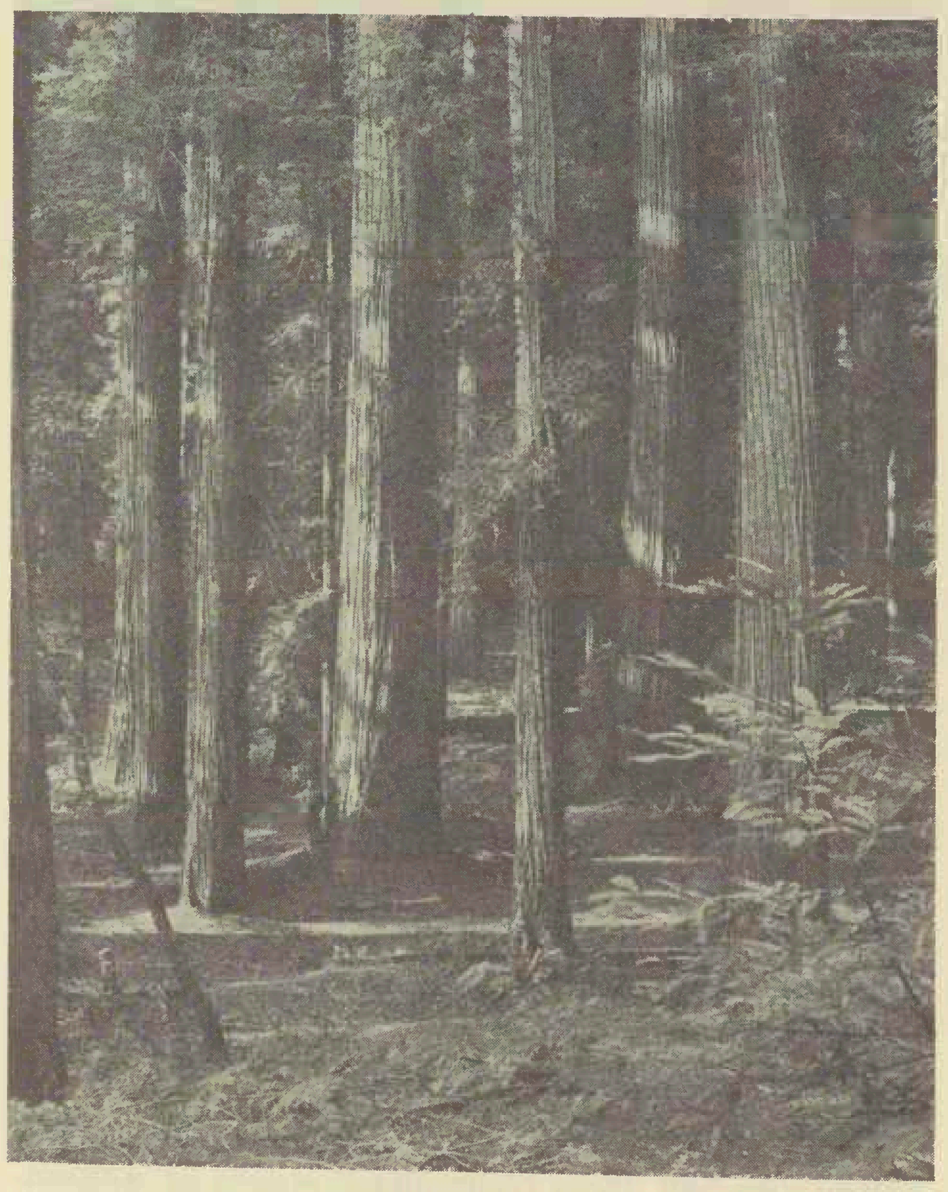


Figure 14.—Redwood forest. (Cedar–hemlock.) Limited to the coast region of California and Oregon; fast disappearing; occupies some potentially agricultural land. Bullcreek Flat, Dyerville, Calif. Photographed by R. T. Fisher.

The Pacific Douglas fir region includes the forests of western Oregon and Washington, and occupies about 54,000 square miles. Up to date there have been utilized from this region nearly 135 billion feet of lumber, cut from something like 4 million acres. Of the total land area, most of which is in forest, 60 per cent of that in the State of Washington is capable of agriculture or grazing, while in Oregon one-third may be classed as tillable land. The climate is generally mild and uniform, with frequent fogs and gradual and moderate changes in temperature. The summers are cool and the winters mild, with an interval of six or seven months between killing frosts.

The so-called Sitka or Alaska spruce belt belongs also to the cedar–hemlock forest region. It occurs in coastal valleys and benches and is associated with western hemlock, western red cedar, and Douglas fir.

Within the cedar–hemlock area agricultural development is limited largely to the lower and more level lands in western Washington and Oregon, where a portion of the cedar and hemlock forests have been cut away or destroyed and the land cleared for agriculture. Oats, wheat, hay, and other forage crops are grown with success within this area. It is also productive of grain crops cut for hay, of clover, and miscellaneous tame grasses, of potatoes, cabbages, onions, and other vegetables, and of fruit. A large proportion of the hops grown in the United States are from this section.

Spruce–Fir Forest. (Fig. 13.)

The high altitude forests, whether of the Rocky Mountains, Cascades, Arizona, or the Sierras, have a similar biological physiognomy peculiar to spruce and alpine fir and may be grouped into one big unit. In the central Rockies, at elevations of from 7,500 feet to timber line (11,000 to 11,500 feet), the predominant stands of this forest are Engelmann spruce–alpine fir. In the mountains of Arizona, at elevations of from 10,000 to 11,500 feet, they are largely Engelmann spruce mixed with bristle-cone pine (*Pinus aristata*) and cork-bark fir (*Abies arizonica*). On the west slope of the Cascades, at moderate elevations, on all aspects, and at altitudes of from 3,000 to 4,500 feet, this type of forest consists largely of the true firs, noble fir (*Abies nobilis*) and red fir (*Abies magnifica*). In some places,

Figure 15.—Mature spruce forest. (Spruce–fir.) In its general aspect it is closely related to the alpine forest of the western mountains, with which it is connected by a more or less continuous belt at northern latitudes. It is best developed in Maine, New Hampshire, and northern New York, where it occurs both in swamps at low elevations and near the upper timber-line. In the Appalachian Mountains it occurs only at high elevations. Adirondack Mountains, N. Y. Photographed by A. Gaskill.

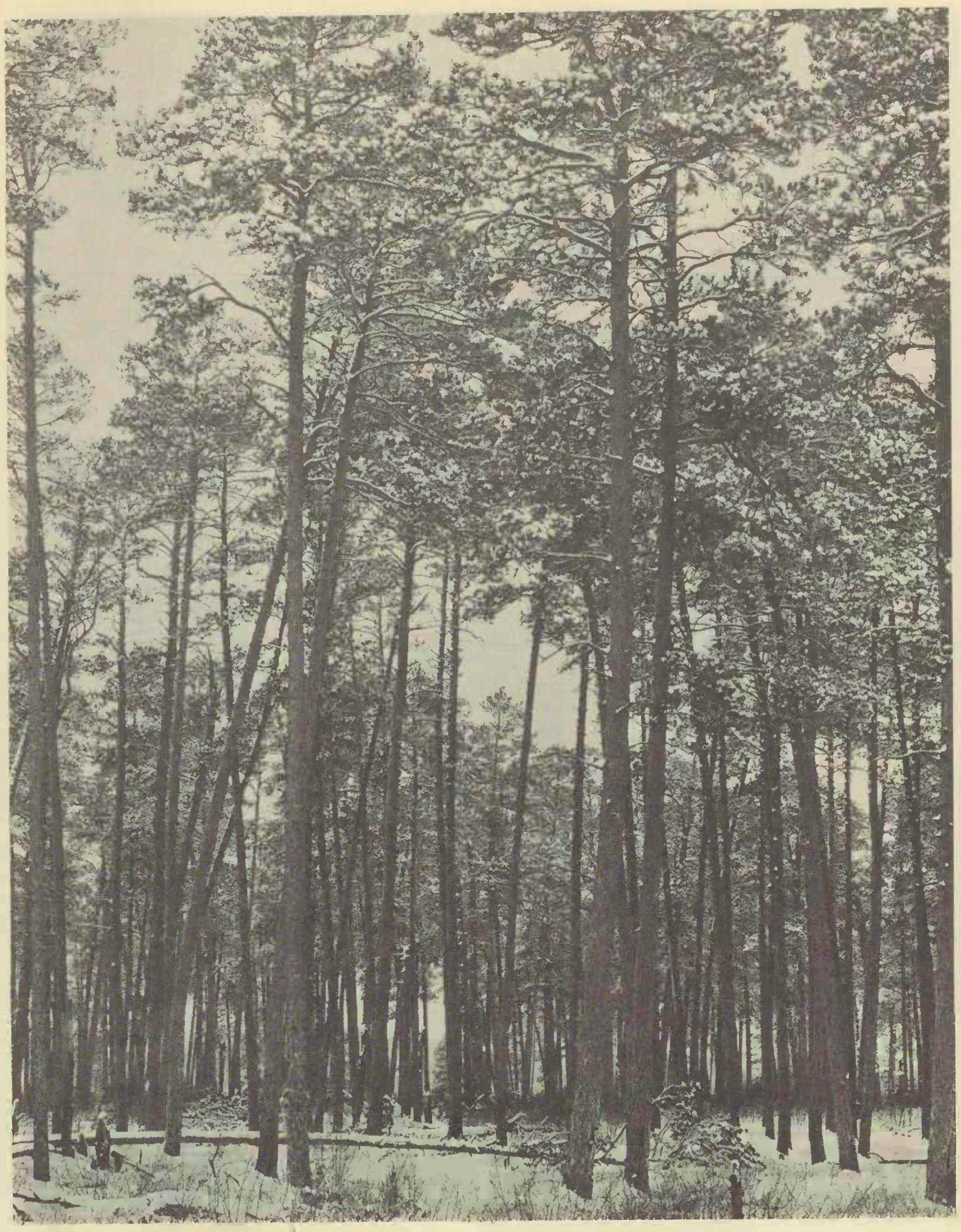


Figure 16.—A mixed stand of Norway and jack pines. (White–Norway–jack pines.) This forest is characteristic of the Lake States. Its appearance is not markedly different from that of the pure lodgepole pine stands of the Rockies and of the scrub pine stands in the southeast. Its composition varies according to the soil. On poor sandy soil jack pine predominates; the heavier soils were originally occupied by white pine, while on the intermediate soils Norway pine forms the principal species. Cass County, Minn. Photographed by A. Gaskill.

as on the Rainier National Forest, noble fir practically forms the timber-line tree. In the Cascades, at elevations of from 4,500 to 7,000 feet, the forest consists of alpine fir, white-bark pine (*Pinus albicaulis*), Lyall larch (*Larix lyallii*), and mountain hemlock (*Tsuga mertensiana*). In the Sierras this belt includes several types. Thus, on cool meadows, with plenty of moisture, varying in elevation from 5,500 to 6,500 feet, it is characterized by pure stands of lodgepole pine. From 7,000 feet to timber line it is made up of alpine fir and mountain hemlock. On northerly and northeasterly slopes in the Sierras, at an elevation above 6,000 feet, it is largely of pure red fir, and at the same elevation, but on less moist and cool situations, it is usually red fir mixed with white fir. These various types all have the biological characteristics typified by the spruce and fir. In most of these stands there are open parks and stream-side meadows which provide excellent summer grazing.

This belt is usually subject to heavy snowfall. The mean annual precipitation is over 30 inches and the temperature low both in summer and winter. The growing season is limited to the three months of June, July, and August, and near the timber line it is shortened to about eight weeks. Throughout the entire belt severe frosts are likely to occur every month in the year, although in Arizona studies have shown that the Engelmann spruce type is free from frost from June 15 to September 15. There has been little agricultural development in this type of forest. This is due chiefly to the unfavorable character of the land surface and to the cool climate and short growing season.

Other Forest Divisions.

Besides the main units, there are other forest communities which do not fit into any of these three large divisions, being remnants of some other forest units now extinct. Among these may be named the largest of these communities—the coast redwood—and such outstanding forest groves as Monterey pine and Monterey cypress which occupy very localized areas and all of which may be classed more or less with the cedar–hemlock series.

The redwood belt (fig. 14).—The redwood belt, although confined to a narrow strip of the humid coast of California, is of great economic importance. It stretches in the form of a belt 400 miles in length and averaging 20 miles in width from the southwest corner of Oregon to near Santa Cruz, California, with an outlier in Monterey County. Within this belt the redwood, although commonly the dominant tree, is usually associated on the slopes with Douglas fir, lowland fir, western hemlock, and tan oak. On the flats or river benches it forms pure stands. In Humboldt and Del Norte Counties of California the redwood forms the heaviest stands of timber in the world.

Figure 17.—Nearly pure stand of white pine. (White–Norway–jack pine.) About 120 years old; contains an admixture of white birch with an understory of balsam; on less sandy soils it is mixed with northern hardwoods. St. Louis County, Minn. Photographed by H. H. Chapman.

There are records of $2\frac{1}{2}$ million feet per acre and 480,000 board feet to a single tree. The redwood belt is characterized by a heavy rainfall in the rainy season and heavy fogs in the dry season, with slight changes of temperature during each day and during the year. The main portion of the redwood belt receives a seasonal average of over 50 inches of rain, but southward the average decreases rapidly, being about 30 inches in the Santa Cruz and Monterey County forests.

Practically the whole redwood belt, with the exception of two public parks, is under private ownership. Until recently the owners sought to convert the logged-off land into agricultural use. The high cost of clearing the land, together with the rapid growth of the trees and their sprouting capacity, proved the land to be more valuable for forest growth than agriculture. Much of this land may, therefore, be kept in forest

EASTERN FOREST REGION.

In the East, because of the less mountainous surface, the natural divisions of the forest coincide chiefly with geographic regions rather than with altitudes, and therefore the line of demarcation between the several divisions into which the eastern forest may naturally be grouped is not as distinct as in the West. The nearest approach to altitudinal distribution of the several main divisions is found in the Appalachian Mountains. However, as in the West, the entire eastern forest vegetation may be classified into a comparatively few fundamental units. Seven main natural divisions are recognized:

(1) Spruce–fir (northern coniferous forest).
(2) White–Norway–jack pine (northeastern pine forest).
(3) Birch–beech–maple–hemlock (northeastern hardwood forest).
(4) Oak (southern hardwood forest).
(5) Cypress–tupelo–red gum (southern river bottom forest).
(6) Longleaf–loblolly–slash pine (southeastern pine forest).
(7) Mangrove (subtropical forest).

Spruce–Fir Forest. (Fig. 15.)

The spruce–fir forest is practically the same boreal coniferous forest which is characteristic of the high altitudes in the West, and which north of the fiftieth parallel merges with the eastern spruce–fir forests. This forest is found in the East both in swamps at low levels and at high altitudes in the mountains. In the low-lying, poorly drained areas, where soil is a muck or peat, spongy in texture, and often acid, the characteristic species are black spruce, balsam, tamarack, white cedar, and some red maple, giving rise to spruce–tamarack swamps, spruce-cedar swamps, or spruce-balsam swamps. At high altitudes it is composed largely of black spruce and balsam fir. On level or rolling flats bordering the swamps, lakes, and water-

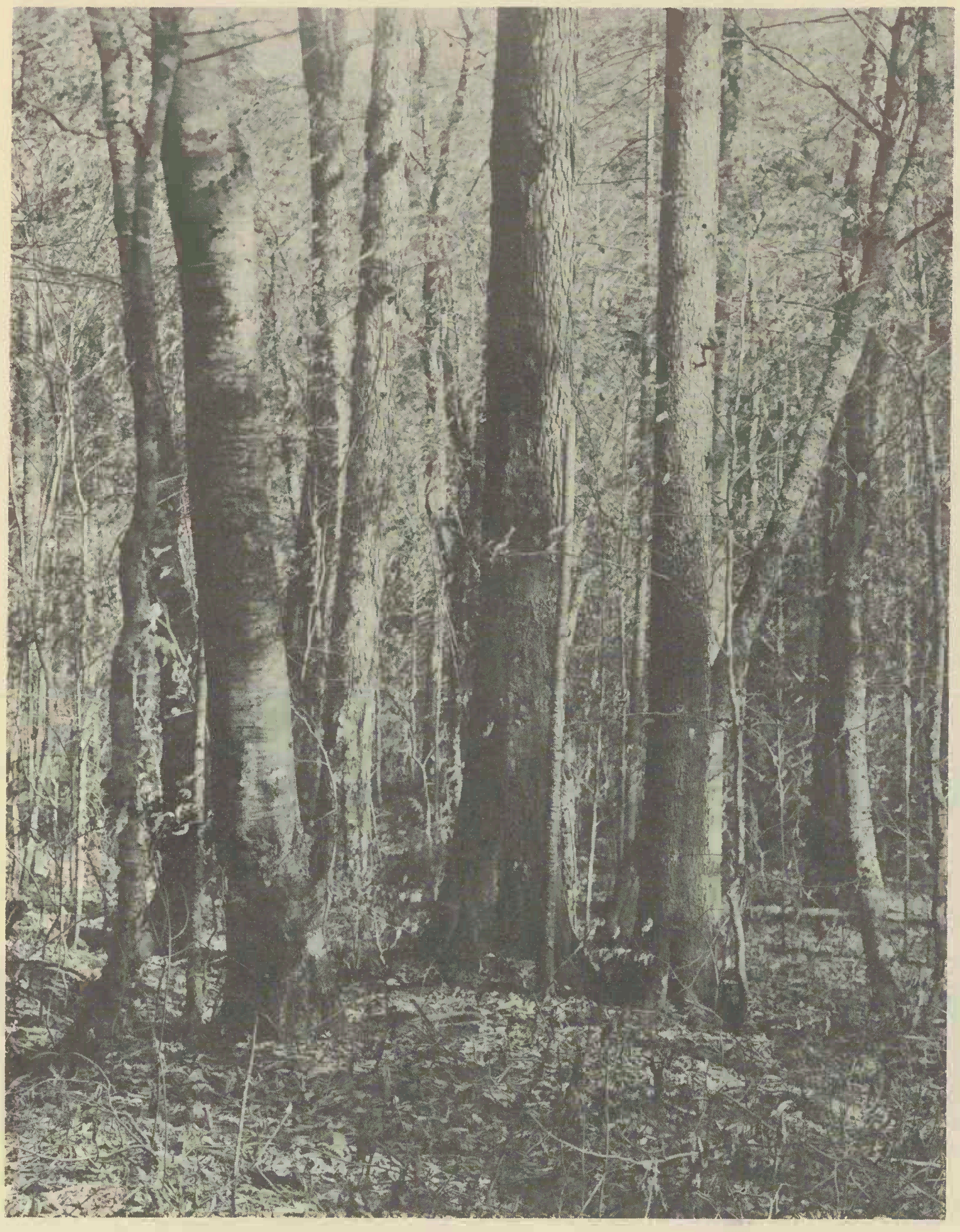


Figure 18.—A mixed forest of birch, beech, maple, white pine, and hemlock. (Birch-beech-maple-hemlock.) It is confined largely to the Lake States, New England, New York, and Pennsylvania. Its boundaries are not always distinct from that of the northern pines, or even spruce and fir. Throughout the region of the northern hardwoods nearly pure stands of white pine or spruce are frequently found. As a rule, the sandy soils in the region are covered with pines, and the heavier soils with hardwoods. The familiar sugar-maple groves are a part of this forest. It is the chief source of the products of hardwood distillation. Adirondack Mountains, N. Y. Photographed by A. G. Varela.

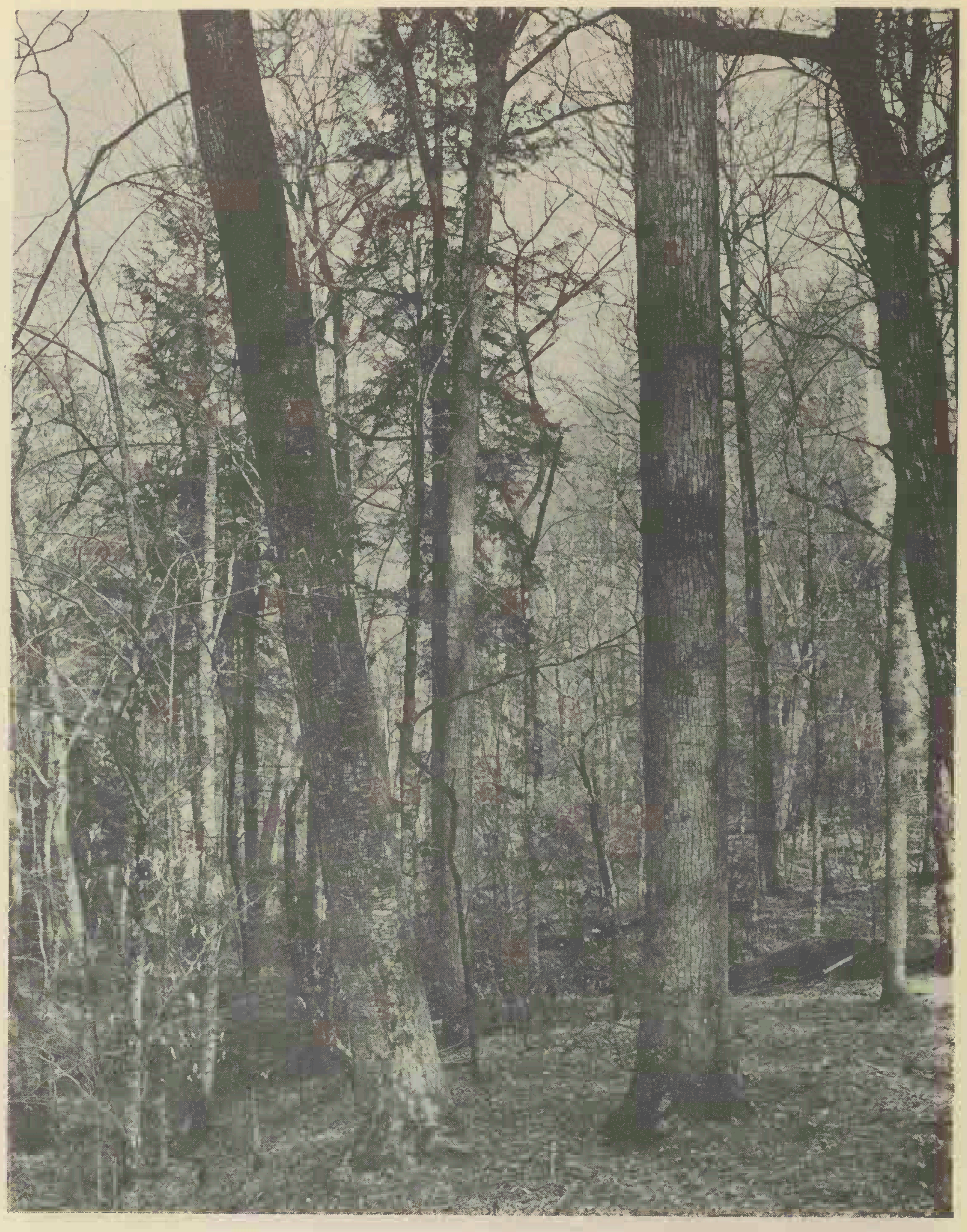


Figure 19.—A mixed forest of yellow poplar and chestnut. (Chestnut-chestnut oak-yellow poplar.) The most valuable temperate hardwood forest in the world. It is not unlike the Pacific coast Douglas fir forest as regards annual precipitation, density of stand, and the development of the individual trees. The similarity is further heightened by the tendency at maturity to develop an understory of hemlock. It differs from the Pacific Douglas fir in part because of the summer rainfall to which may be assigned the preponderance of hardwoods in the Appalachian Mountains and the lack of which accounts for the absence of hardwoods in the Northwest. North Carolina. Photographed by F. G. Plummer.

courses the forest is made up of combinations of red spruce, birches, red maple, white pine, eastern hemlock, and balsam fir. This type of forest is in a large measure a transition between the swamp type and the type of mixed hardwood lands higher up. On the higher benches and the lower mountain slopes, where the soil is deep, fresh, and well drained, red spruce is an associate of hard maple, beech, and balsam fir, with a scattering of eastern hemlock, white pine, birch, cherry, and a variety of other species. The proportion of species in mixture depends on topographic conditions. The finest stands of pure red spruce are occasionally found on the steepest slopes in the region. Although the spruce-fir forest is found also throughout practically the entire birch-beech-maple-hemlock region, it is chiefly confined to the Northern States, where its upper altitudinal limit may be set at about 4,000 feet above sea level. It is also found in the mountains of North Carolina and Tennessee, but at increasingly higher altitudes. It finds its upper limit there between 5,000 and 6,000 feet.

The climatic characteristics and the agricultural importance of this forest division are about the same as that of its western extension. There is this difference, however, that the eastern spruce-fir forests, being to a large extent on low but level land, and therefore capable of being drained, offer greater agricultural possibilities than similar stands at high altitudes in the West.

White-Norway-Jack Pine Forest (Northeastern Pine Forest). (Figs. 16 and 17.)

The mixed pine forest of jack pine, Norway pine, and white pine is confined largely to the Lake States. Stands of pure white pine (fig. 17), or with some admixture of Norway pine, are found throughout the Northeastern States, chiefly on sandy soils. Stands of pure white pine, for instance, were found throughout the hardwood forests of the Adirondack region in New York, along the Hudson River, and in the Catskills. Pure white-pine stands occur on sandy plains and throughout the broadleaf forests which cover the remainder of the State. In Pennsylvania vast forests of white pine and eastern hemlock covered both flanks of the Allegheny Mountains; the headwaters of the Susquehanna River were heavily wooded with white pine. In New England white pine seldom formed solid bodies of large extent, but usually grew mixed with spruce and other conifers and hardwoods. Pine forests stretched along the valleys of the Connecticut and Merrimac Rivers and grew along the shores of Lake Champlain in western Vermont.

The most extensive and the densest white-pine forests in the country were found in Michigan. It was abundant in the northern part of the lower peninsula,

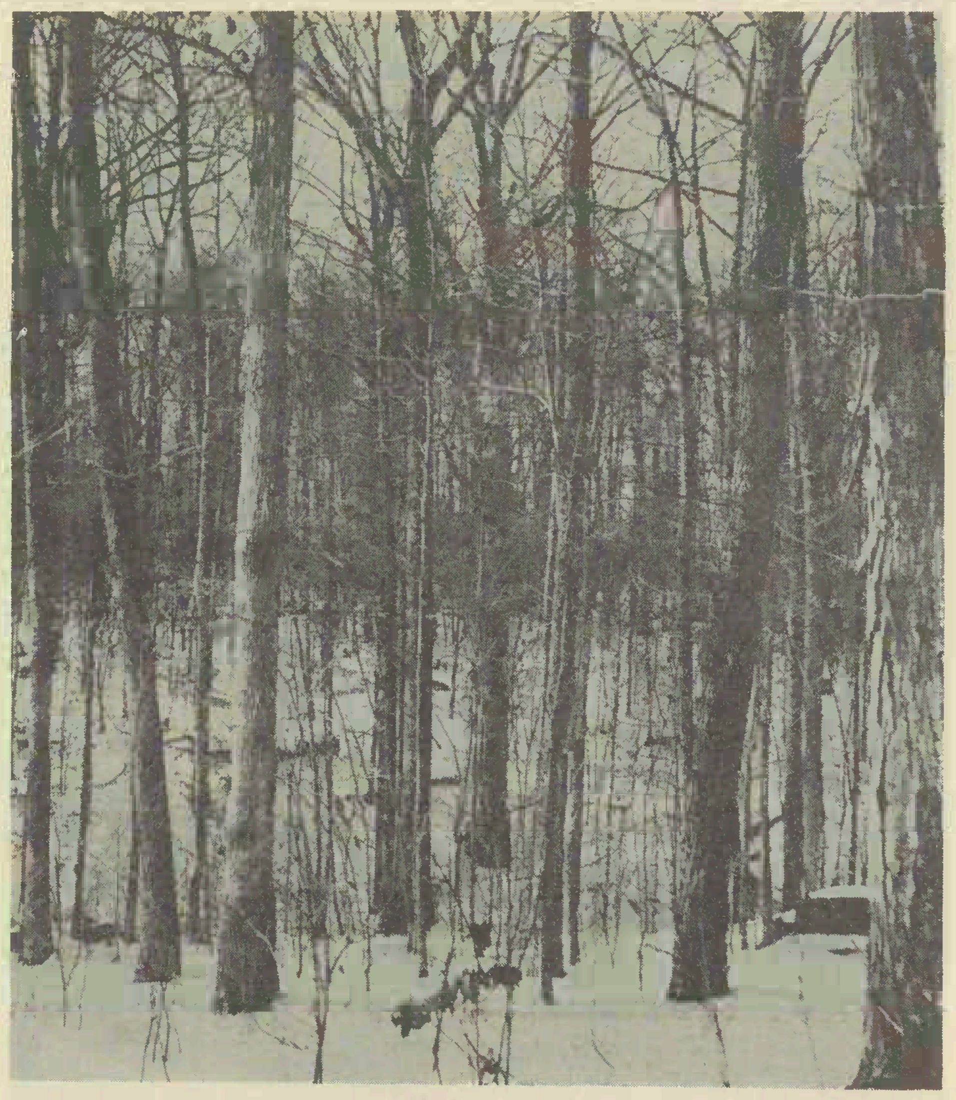


Figure 20.—A mixed forest of white oak, shagbark hickory, and pignut hickory. (Oak-hickory.) Originally it was the source of the most valuable white oak timber. Most of the virgin timber, however, in the northern and eastern part is now cut out and the land is devoted to agriculture. On the east this forest gradually merges with the chestnut-chestnut oak-yellow poplar forest, which now furnishes the bulk of the southern hardwoods. It is characteristic of dryer climatic conditions and extends farther into the prairie region than any other hardwood forest, finally giving way to the cottonwood, box elder, elm, and other trees along the water courses. La Porte County, Northern Indiana. Photographed by H. Foster.

where, on the sandy loam soils, it grew in immense, practically pure forests, and on the heavier loams interspersed among hardwoods. In the northern peninsula, especially in the basin of the Menominee River, it covered the sandy plains almost to the exclusion of other species.

In Wisconsin there were fewer pure stands of white pine except on gravelly or sandy soils. In mixture with hardwoods, however, white pine was very abundant.

In Minnesota white pine forests were confined to the northern and central portions of the State. They were not so extensive as those in Michigan, but were very prominent in mixture with hardwoods.

In the Lake States the composition of the stand depends on the character of the soil. On the poorer sandy soils and farthest north the stands consist almost exclusively of jack pine. On moderately poor sandy soils Norway pine occurs either pure or in mixture with jack pine, while on the richer soils and on well-watered sandy flats it is found in mixture with white pine and also northern hardwoods. The jack pine plains, like the lodgepole pine forests of the West, have been extending their area as a result of repeated fires. The original Norway pine formed at least 10 per cent in all jack pine stands, but as a result of fire this proportion has been decreased until most of the sandy plains are now pure jack pine.

The Norway pine-jack pine forests, which are particularly characteristic of Wisconsin, Minnesota, and Michigan, are not unlike the lodgepole pine forests of the northern Rockies. The climate of these northern pineries in the Lake States is characterized by an annual rainfall of from 25 to 35 inches and extreme temperatures of from —50° to 105° F. In some parts of this forest region frosts may occur every month in the year. The last killing frost, however, usually occurs about May 15 and the first autumn frost by September 20.

Birch-Beech-Maple-Hemlock Forest. (Fig. 18.)

This northern hardwood forest is found in greater or less abundance within the drainage systems of the St. Lawrence, the Great Lakes, and the upper Mississippi as far south as southern Minnesota; throughout northern New England, and southward along the northern and southern Appalachian Mountain ranges to extreme northern Georgia. The area occupied by the northern hardwoods is probably over 50,000,000 acres, nearly half of which is in the Lake States. It occupies the fresh, well-drained, fertile soils, and its more characteristic hardwoods are sugar maple and yellow birch. The geographical extent of the northern hardwood forest practically coincides with the range of yellow

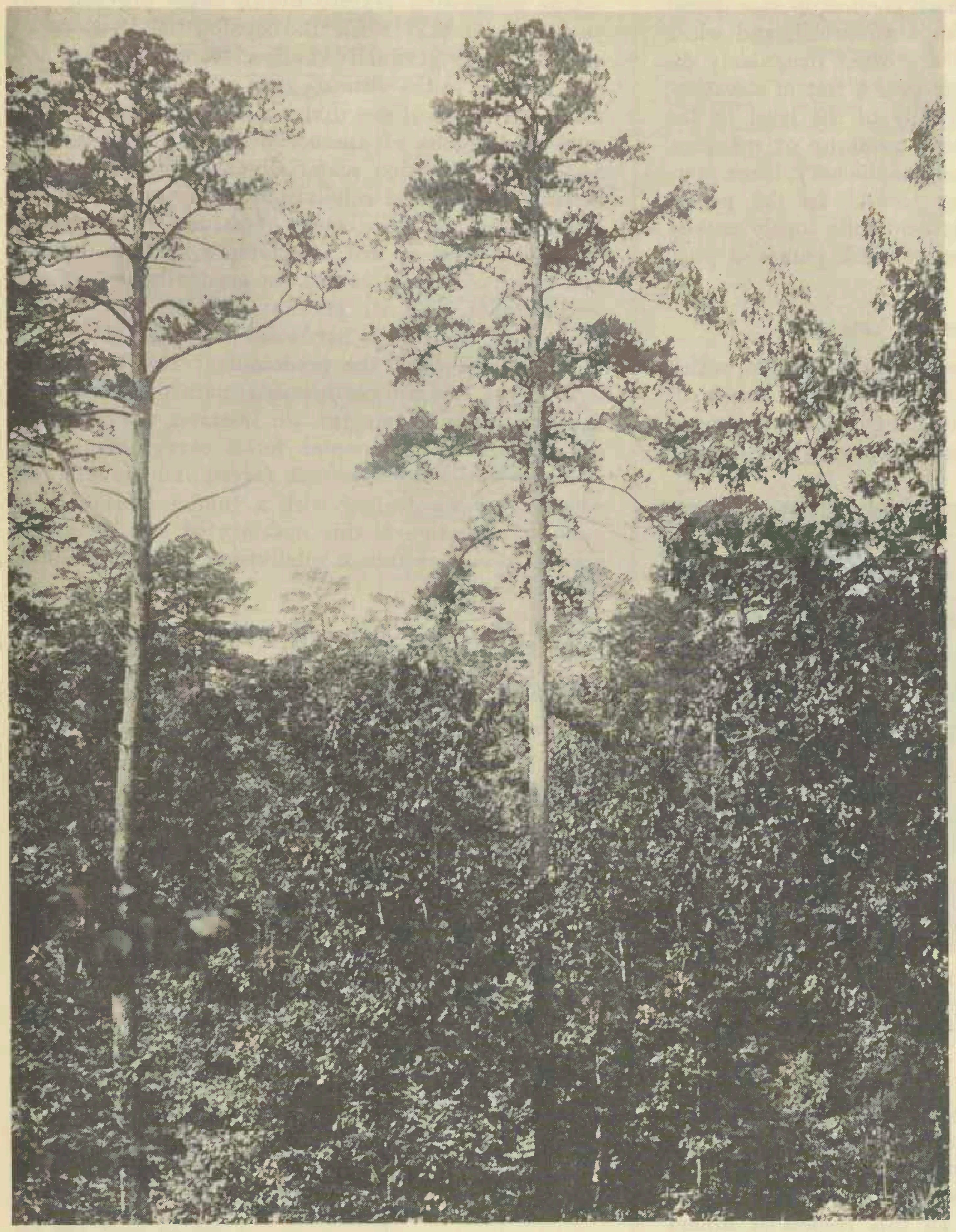


Figure 21.—A mixed forest of shortleaf pine and oak (Oak–pine), most characteristic of the Great Piedmont Plateau. In a sense it is a transition zone between the oak forest to the north and the southern pineries to the south. In some respects it is similar to the mixed forest of northern hardwoods with northern pines to the north of the oak region. The type varies considerably in composition according to the altitude and proximity to the coast; loblolly pine and other southern pines enter into the composition. Garland County, Ark. Photographed by A. G. Varela.

Figure 22.—A mixed forest of longleaf pine, loblolly pine, and shortleaf pine (Longleaf–loblolly–slash pines), typical of the Coastal Plain, and varying in composition from pure stands of longleaf to a mixed pine forest in which several species of southern pines occur. The typical longleaf pine forest is not unlike the yellow pine forests of Arizona (see fig. 8). This forest is at present the only source of commercial naval stores in the country. It is also at present the chief timber-producing region in the United States. Georgia. Photographed by E. Block.

birch, and it centers about the region in which the white pine lumbering industry developed.

This northern hardwood forest is distinctly *humid*, and the composition of the forest is therefore influenced chiefly by *temperature*, except in its western extension, where moisture may be considered one of its limiting factors. The growing season within this forest is approximately five months, from May to September, inclusive. The average temperature for the growing season is about 61° F., while for the oak forest or so-called southern hardwoods it varies from 64° to 67°. During the growing season the total average precipitation in the northern hardwood forest is from 18 to 23 inches.

The birch–beech–maple–hemlock forest is of widely varying composition. It is found in a great variety of mixtures with spruce, fir, beech, sugar and red maples, white pine, and hemlock, and with scattered individuals or groups of other species, notably paper birch and aspen. Elm and basswood are also frequent components of this forest. In the Upper Peninsula of Michigan and in the northeastern part of Wisconsin the hardwoods are typical northern hardwoods, maple, yellow birch, and beech, with their characteristic associate, hemlock. In Minnesota this character of forest peters out, and what is known as the hardwood forest is almost exclusively popple, white birch, and occasionally basswood and maple of inferior development. The northern hardwoods occupy some of the best agricultural land of the northeastern United States. The principal crops in this region are timothy, clover, oats, barley, corn, especially for silage, potatoes and beans. Fruit, especially apples, strawberries, and bush fruits, are successfully grown, and where markets are available truck gardening has proven profitable.

The birch–beech–maple–hemlock forest in its biological characteristics is not unlike the western white-pine forests of northern Idaho and western Montana. Here the eastern white pine (*Pinus strobus*) takes the place of the western white pine (*Pinus monticola*). Hemlock also plays the same part as there, being the last stage in the development of the stand and coming in as an understory. The place of the western red cedar, however, is taken in the East by such hardwood species as sugar maple, beech, yellow birch, and the lowland white fir is represented by balsam fir. Were it not for the difference in the distribution of rainfall during the year, the composition of the forests of the two regions would possibly be even more closely similar.

The Oak Forest (Southern Hardwood Forest).

The lower slopes in the Appalachian region and the central Mississippi Valley support a hardwood forest in which the oaks make up the great body of the forest. It may therefore be characterized as the oak region. This hardwood forest is probably the largest hardwood

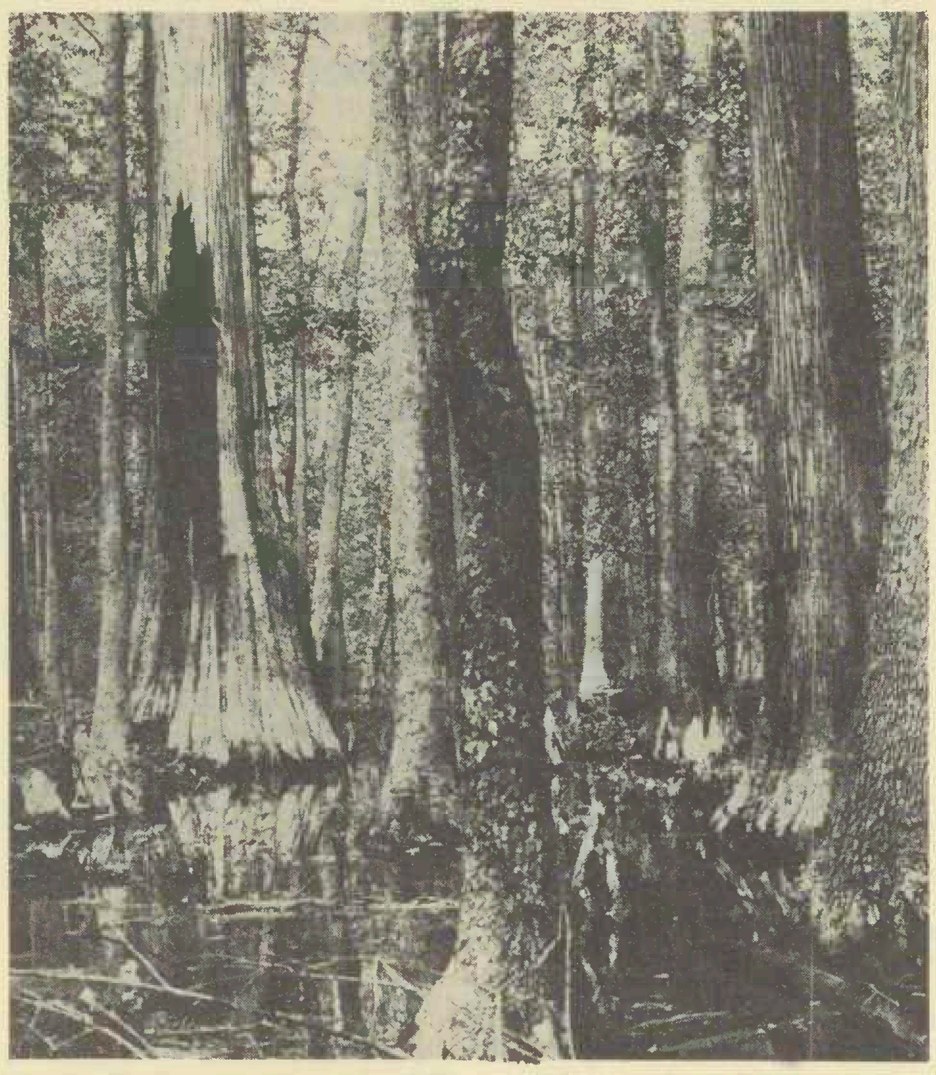


Figure 23.—A mixed forest of cypress and tupelo gum on low land. (Cypress–tupelo–red gum.) Few other forests present such a variety in composition as the bottom-land forest of the South. Where water stands for the larger part of the growing season, it is made up largely of cypress and tupelo gum. On the bottom lands where it is overflowed for only a few months or weeks there is, besides cypress and tupelo, ash, cottonwood, and white and red bays. On the dryer ridges within the bottom lands it resembles the hardwood forests of the vicinity, made up of red gum, black gum, ash, red maple, water oak, and hickory. New Dexter, Stoddard County, Mo. Photographed by Z. L. Bliss.

forest in the Temperate Zones of the world. Close to markets and surrounded by densely populated country it is recognized as the great center of the Nation's hardwood resources.

There is a certain parallelism between the oak region, particularly the eastern part of it, composed of chestnut, chestnut oak, and yellow poplar forests, and the Pacific coast Douglas fir. There is a similar heavy precipitation, density of stand, and development of the individual trees. If to this is added that hemlock and white pine are not lacking in the typical cove stands, the comparison becomes particularly strong. If the southern hardwoods, especially the southern Appalachian hardwoods, have the tendency at maturity to develop an understory of hemlock just as the northern hardwoods do, the two divisions of our hardwood belt may be considered as belonging to one forest unit just as do the western white pine-larch region and the Pacific coast Douglas fir. The life history, however, of most of the southern Appalachian stands is still imperfectly known. Therefore the present birch–beech–maple–hemlock forests and the oak region must be classed as two separate forest units.

This hardwood forest belt was originally continuous and of great luxuriance, but the greater part of it has now been cleared for agriculture or turned into brush land. There are still large areas, however, of virgin hardwood forest, particularly in the Appalachians, Tennessee, Kentucky, Missouri, and Arkansas.

Although greatly modified by repeated surface burning and heavy destructive culling, this region can still be clearly divided into three distinct areas:

The chestnut–chestnut oak–yellow poplar forest.
The oak–hickory forest.
The oak–pine forest.

Chestnut–chestnut oak–yellow poplar forest (fig. 19).—This forest is found throughout the greater portion of the highland extending from Pennsylvania into northern Mississippi and Alabama. It is best developed in the southern Appalachians, between and including the great Blue Ridge and Unaka Mountain systems. The region is generally mountainous, but not craggy, with steep slopes, narrow coves, ridges, and some high and broken or gently sloping land, which approaches table-land. The annual precipitation is from 50 to 70 inches, the heaviest coming in July and August. With much sunlight, evaporation is relatively rapid. The growing season is from five to six months long. Although chestnut, chestnut oak, and yellow poplar are the characteristic species of this forest belt and distinguish it from the hardwood belt west of it, many other kinds of trees are found in this forest; in fact, it contains probably a larger number of species than any other forest area in North America.

The oak-hickory forest (fig. 20).—In the western part of the oak region, embracing western Ohio, In-

diana, Missouri, and Oklahoma, and largely bordering on the prairies (fig. 25), the chestnut, chestnut oak, and yellow poplar gradually disappear and the forest becomes characteristically an oak-hickory forest. The oaks and the hickories, together with some ash, black walnut, elm, and box elder, are the species which push farthest into the prairie region. Hickory is particularly predominant in the lower Mississippi Valley in western Tennessee, eastern Arkansas, and northwestern Mississippi.

Oak–pine forest (fig. 21).—The broad Piedmont region lying between the Appalachians and the Atlantic Coastal Plain from Virginia to South Carolina, the northern half of Georgia, Alabama, Mississippi, and Louisiana, most of Arkansas, and through eastern Oklahoma and eastern Texas, is occupied by a mixed forest of pines and southern hardwoods. The principal pine is shortleaf, although scrub pine enters prominently in parts of Virginia and North Carolina, especially in old fields and on the poorer soils, dry pastures, and waste places. On the heavier, moister soils loblolly pine becomes the principal pine in mixture. Over the Northern Atlantic States this mixed oak–pine forest consists of shortleaf pine, pitch pine, chestnut oak, yellow oak, and red oak. From Virginia southward throughout the Piedmont section, lying between the Coastal Plain and the upper slopes of low mountains up to 2,500 feet, the forest is composed of upland oaks, hickories, and shortleaf pine. In the hilly and mountainous parts of Arkansas this mixed pine–hardwood forest is found at elevations from 1,000 to about 2,000 feet. West of the Mississippi River this forest is made up of shortleaf pine, oaks, and hickories, particularly yellow oak and bitternut and pignut hickories; on the dry ridges post and blackjack oaks; in the fresher soils white and red oaks, big–bud or mockernut hickory, and red gum.

The great oak forests once occupied the best agricultural land in the eastern portion of the United States. The oak–hickory portion covered much of the fine farm land of Ohio and Indiana and extended up along the river bottoms in many of the central Mississippi Valley States. Winter wheat, corn, oats, and hay, mostly timothy and clover, are the principal crops grown in this region. Sweet corn, onions, and peas are grown locally in the northern portion, tomatoes and melons in the southern, while throughout the region apples, peaches, and bush fruits are produced. The chestnut, chestnut oak, and yellow poplar area is well adapted for general farming. Corn, wheat, oats, timothy and clover hay are grown in the northern portion. Apples and peaches are likewise produced in this area. The oak-pine lands of the Piedmont Plateau are somewhat similar in their agricultural productiveness to those indicated by the chestnut and tulip or yellow poplar, and are especially adapted to the production of tobacco and cowpeas. Corn, winter wheat, oats, and vegetables for home use are the important crops within this area, and in the southern portion cotton.

Longleaf–Loblolly–Slash Pine Forest (Southern Pineries). (Fig. 22.)

This forest occupies a belt which extends through the Coastal Plain from extreme southern Virginia to the Everglades in Florida and Trinity River in Texas. It is made up of 10 different species of pine, of which, however, the longleaf pine is the most abundant and occupies extensive areas. This forest, besides furnishing at present a large part of the timber cut of the country, is the source of the naval stores of the United States.

Although the region is one of heavy precipitation (from 40 to 60 inches), with a growing season covering from 6 to 12 months in a year, the sandy soil and the rapid evaporation make the vegetation resemble in many respects the pure forests of western yellow pine. The longleaf pine forest has the same open parklike character and the ground is covered with coarse grasses or low shrubs.

The principal crops grown in this region are cotton, corn, peanuts, sweet potatoes, and velvet beans. The production of winter vegetables is also important locally.

Cypress–Tupelo–Red Gum (Riverbottom Forests). (Fig. 23.)

The bottom-land areas are occupied by forest stands which near the Gulf coast are characterized by the presence of cypress, red gum, tupelo, yellow oak, overcup oak, and cow oak, and farther north by cottonwood, silver maple, white elm, river birch, sycamore, boxelder, and ash. In most of the river bottoms there are distinguished three situations, namely, the "glades," the "ridges," and the "back sloughs." The sloughs remain under water during the larger part of the growing season and their characteristic forest growth is cypress and tupelo gum. The glades are those parts of bottoms which are subject to overflow for from a few weeks to several months. They support a forest of cypress, tupelo, water ash, cottonwood, and white and red bays. The glades are often irregularly divided by lower ridges, seldom over 6 feet in elevation, and often sloping imperceptibly to the level of the glades. They support a forest made up of red gum, slash pine, overcup oak, water oak, hickory, black gum, ash, red maple, and honey locust. In the poorer drained swamps with highly acid soils tupelo usually is absent and the pond pine, or black gum and pine, make up the stand.

The Mangrove (Subtropical Forest). (Fig. 24.)

The mangrove (*Rhizophora mangle*) thickets, which cover hundreds of miles on the southern shores of Florida, are representative of the tropical forest vegetation. The principal areas occupied by it are the

Figure 24.—Mangrove thicket (Mangrove), typical of the moist subtropical forest along the Florida coast. It occurs on land submerged by salt tide-water, where it builds up a foundation for other species. Miami, Fla.

shoals lying between the keys and the mainland, which are composed of calcareous sediment, and the low southern and western borders of the Everglades. It occurs on shores and shoals that are overflowed generally by salt tidewater. In this respect it differs from cypress, in that the latter grows in localities that are overflowed at times by fresh water. In these localities and on tidewater islands as far north as latitude 29° it forms dense thickets. In places on the mainland shores the mangrove attains treelike dimensions, forming a tall trunk sometimes 2 feet in diameter. Mangrove thickets in the course of time build up a foundation for other species. Of these, black mangrove is the most important.

CORRELATION OF FOREST VEGETATION.

There is a similarity in distribution of these large forest units in the East. Taking the oak forest as the center, both north and south of it there is a forest

Figure 25.—A mixed forest of white elm, green elm, hackberry, box elder, and cottonwood along water courses in the prairie. (Tall grass and oak–hickory). The most western extension of the oak–hickory type. Fairport, Kans. Photographed by W. L. Hall.

of hardwoods mixed with pines. In the North the birch, beech, and maple—northern hardwoods—have a large admixture of white pine and hemlock; in the South the shortleaf pine and oak form a forest belt typical of almost the entire Piedmont region. Next to this mixed hardwood and pine belt, North and South, we come to pure pineries. In the North it is the white pine, Norway pine, and jack pine; in the South, longleaf, loblolly, and slash pines. Immediately north of the white pine, Norway pine, and jack pine forest we find the Arctic forest belt of spruce and fir, and south of the longleaf, slash, and loblolly pines we find the tropical fringe of mangrove.

One interesting feature of all these big units of vegetation is that while the smaller subdivisions of each unit may gradually change into one another and all gravitate to the ultimate type of the main division, the subdivisions of one division do not readily change into subdivisions of another division unless the climate in the division materially changes. Thus, for instance, the several subdivisions of the great central oak forest, both in the course of natural evolution and under the effect of fire, interference by man, insects, and other accidental causes, do gradually change one into another, and all gravitate, if left undisturbed for a long time, to a hardwood formation in which the oaks will form the predominant feature; yet as long as the climatic conditions remain the same, it is hardly possible to imagine, for instance, the chestnut–chestnut oak–yellow poplar forest ever turning into a longleaf–slash–loblolly pine forest, and the true test whether we are dealing with a fundamental natural unit of vegetation is this inability of smaller subdivisions to change into a subdivision of another main division.

SUMMARY OF FOREST VEGETATION.

Classification of forests of the United States into forest regions, subregions, and sites.

THE WESTERN FORESTS.

Forest region.	Subregion.	Association.	Sites.
Western yellow pine–Douglas fir.	Lodgepole pine.	Lodgepole pine–Douglas fir.	At the lower altitudinal limit of the lodgepole pine zone, on south slopes and on dry, rocky knolls.
		Lodgepole pine–Engelmann spruce.	At the upper altudinal limit of the lodgepole pine zone and on moist bottom lands along stream courses.
		Larch–lodgepole pine.	On flats and drier situations in northwestern Idaho.
	Pure yellow pine.	Pure yellow pine..	Occurs on dry, hot slopes or flats at low elevation, from 3,500 to 4,500 feet in California and on the east slope of the Sierras, where it consists of Jeffrey pine and white fir. Typical of Arizona and New Mexico. In the southern part of each of these States the belt lies between about 6,000 and 7,500 feet. At its upper edge Douglas fir and Engelmann spruce come in and above 9,000 feet dominate the stand. In the northern part of New Mexico these forests are nearly 1,000 feet higher. Also occurs in northern Nebraska and the Black Hills, in northern Nebraska at an elevation of 3,000 feet, and in the Black Hills from 3,000 to 5,000 feet. Also on south s opes and all lower altitudes in Washington and Oregon' between 3,000 and 5,500 feet. In northern Montana and Idaho at the lower altitudes on warm, sunny exposures, low ridges, and rather dry benches and gravelly flats.
	Rocky Mountain Douglas fir.	Yellow pine–Douglas fir.	On northwesterly moderately cool slopes at moderately high elevations (4,500 to 5,500 feet) on the west slope of the Sierras. In Arizona this type occurs at elevations between 8,500 to 10,000 feet on the south slopes and between 7,500 feet and 9,000 feet on the north exposures; in the central Rockies at elevations from 6,000 to 9,000 feet, chiefly on sandstone and granite soils.
		Douglas fir........	On cool northerly and northeasterly slopes at elevations of about 5,000 to 6,000 feet on the moist slopes of the Sierras and at elevations between 8,000 and 10,000 feet in the central Rockies.
		Yellow pine–Douglas fir–larch.	On moderately westerly slopes throughout northwestern Idaho.
	Yellow pine–sugar pine–incense cedar.	Yellow pine–sugar pine.	On cool slopes, chiefly on clay, slates, quartzite, and limestone soils at elevations of 3,500 to 5,500 feet on the western slope of the Sierras.
		Yellow pine–incense cedar.	On moderately dry western slopes, especially on soils of serpentine formation on the western slope of the Sierras.
		Yellow pine–sugar pine–Douglas fir.	On cool slopes on clays, slates, quartzites, and limestones, at elevations of from 4,000 to 6,000 feet on the west slope of the Cascades.
Cedar–hemlock (*Thuja–Tsuga*).	Western larch-western white pine.	Pure western larch.	On flats and moderate northerly and northwesterly slopes in northwestern Idaho.
		White pine–Douglas fir–larch.	On moist northerly slopes, flats, and basins at various elevations up to the point where alpine fir and Engelmann spruce take possession throughout northwestern Idaho.
		White pine–larch–cedar.	Practically the same as for the previous one, except that it is in a more advanced stage of maturity.
	Pacific Douglas fir.	Douglas fir–hemlock–cedar.	On humid lower slopes and valleys from sea-level to 3,000 feet.
		Pure Douglas fir..	On lower slopes and valleys moderately humid, from sea-level to 3,000 feet.
		Sitka spruce.......	Coastal valleys and benches from sea-level to 200 feet.
		True firs..........	Middle altitudes on all slopes and aspects, from 3,000 to 4,500 feet, on the west slope of the Cascades.
Spruce–fir (*Picea–Abies*).	....	Alpine fir–white bark pine–Lyall larch.	At high altitudes above the commercial forest, from 4,500 to 7,000 feet, in the Cascades.
		Engelmann spruce-bristle-cone pine–cork-bark fir.	At elevations from 10,000 to 11,500 feet in the mountains of Arizona.
		Pure red fir.......	At elevations above 6,000 feet on northerly and northeasterly slopes in the Sierras.
		Red fir–white fir..	At same elevation as that of red fir (6,000 feet), but on less moist or cool situations.
		Sub-alpine fir–hemlock.	From 7,000 feet to timberline in the Sierras.
		Lodgepole pine....	On cool meadows with plenty of moisture, varying in elevation from 5,300 to 65,000 feet, in the Sierras.
		Engelmann spruce–balsam fir.	At elevations from 7,500 to 10,000 feet, in the central Rockies.

Classification of forests of the United States into forest regions, subregions, and sites—Continued.

THE WESTERN FORESTS—Continued.

Forest region.	Subregion.	Association.	Sites.
Piñon-juniper.	....	Piñon-juniper....	In central Rocky Mountains, Rocky Mountain juniper (*Juniperus scopulorum*) and one-seed juniper (*J. monosperma*) are the chief species, often with some Gambel oak (*Quercus gambelii*) and western yellow pine. In Arizona and New Mexico piñon, Mexican piñon (*P. cembroides*), single-leaf piñon (*P. monophylla*), alligator juniper (*Juniperus pachyphloea*), one-seed juniper, Rocky Mountain juniper, and Utah juniper (*J. utahensis*) are the chief species, often with some Gambel oak and western yellow pine. In Utah, singleleaf piñon, Utah juniper, one-seed juniper, and Rocky Mountain juniper, often with some Gambel oak and western yellow pine. In California, single-leaf piñon and Utah juniper, often with some western juniper (*J. occidentalis*) and Jeffrey pine.
		Juniper..........	In the northern Rocky Mountains juniper is the chief species, usually with some limber pine, western yellow pine, or Douglas fir; in California, juniper, often with some Jeffrey pine and western yellow pine; in Washington and Oregon, western juniper, often with mountain mahogany, and sometimes with a little western yellow pine.
Chaparral.....	....	Oak............	In Arizona and New Mexico Emory oak (*Q. emoryi*), Arizona white oak (*Q. arizonica*), blue oak (*Q. oblongifolia*), and whiteleaf oak (*Q. hypoleuca*) are the chief species, often with some alligator juniper, Mexican piñon, and other species. In Utah, pretty scrubby Gambel oak. In California, black oak (*Q. californica*), California blue oak (*Q. douglasii*), canyon live oak (*Q. chrysolepis*) California live oak (*Q. agrifolia*), highland live oak (*Q. wislizeni*), valley oak (*Q. lobata*), and Garry oak (*Q. garryana*), often with some digger pine, madroñe, and occasionally knobcone pine, Coulter, Jeffrey, and western yellow pines, and other species.
		Digger pine.......	A low foothill belt made up approximately of 40 per cent or more of digger pine, often mixed with various oaks, Coulter pine, western yellow pine, and other species. Occurs on any sites below the western yellow pine type.

THE EASTERN FORESTS.

Forest region.	Subregion.	Association.	Sites.
Spruce–fir.....	Spruce–fir.....	Spruce swamps...	Low lying, poorly drained areas, whose soil is a muck or peat, spongy in texture, and acid. The characteristic species are red spruce, black spruce, balsam, tamarack, cedar, soft maples.
		Spruce flats.......	Spruce flats occupy the level and rolling flats bordering the swamps, lakes, and water courses. It is in large measure a transition between the swamp type and the type of the mixed hardwood lands, and in many respects exhibits the characteristics of each. Spruce, birch, soft maples, white pine, hemlock, and balsam are the characteristic trees in mixture.
		In mixture with hardwoods.	These occupy the best soil sites of the region, usually the benches and the lower mountain slopes. The soil is here best adapted to hardwood growth, is deep, of more or less even texture, fresh, and well-drained. Besides spruce, hard maple, beech, and birch predominate and there is a scattering of hemlock, white pine, soft maple, cherry, and a variety of other species. The proportion of spruce in mixture depends on topographic conditions. Transition to birch-beech-maple-hemlock forest.
Birch–beech–maple–hemlock (northern hardwood forest).	....	With mixture of spruce, balsam and hemlock (transition forest); with mixture of white pine or tamarack; with mixture of ash, elm, basswood, or red oak; with mixture of paper birch or aspen; with beech predominating; with yellow or black birch predominating; with sugar maple predominating.	Fresh, well-drained fertile soils within the drainage system of the St. Lawrence, the Great Lakes, and the upper Mississippi; throughout northern New England and southward along the northern and southern Appalachian Mountain ranges to extreme northern Georgia. It coincides with the range of yellow birch and centers about the region of best development of white pine. In Minnesota the beech and hemlock disappear and the forest is made up of aspen, white birch, basswood, and maple of inferior development.
White pine–Norway pine-jack pine.	....	Jack pine plains...	On the driest, sandiest soils.
		Pure Norway pine.	On dry, sandy soils, slightly better than those characteristic of the jack pine plains.
		Norway-white pine in mixture with hardwoods.	Usually on moderately moist, well-drained soil underlain with a clay subsoil.
Oak..........	Chestnut–chestnut oak–yellow poplar.	....	*Cove.*—Poplar, hemlock, basswood, black birch, cucumber, ash, buckeye. *Most abundant*, probably chestnut. *Very abundant*, chestnut, oak, hickory, red oak, white oak, black gum, dogwood, sourwood, silver bell, white pine. There may be distinguished poplar cove, hemlock cove, white oak cove, etc. *Ridge.*—Pitch table-mountain, and short-leaf pines; chestnut, scarlet, and black jack oaks; chestnut; black gum. There may be recognized pine ridge, chestnut oak ridge, oak ridge. *Slope.*—A blending of above species, with heaviest proportion of chestnut and oaks. Upper slope resembles ridge, lower slope resembles cove.
	Oak–hickory..	....	The most eastern extension of the oak region. The oaks and the hickories, together with some ash and black walnut, are the farthest avant post in the prairie region.
	Oak—shortleaf pine.	....	Characteristic species are chiefly shortleaf pine as the predominating species, with varying amounts of black, chestnut, post, and Spanish oaks, pignut and mocker-nut hickories, and black jack oak, approximately in the sequence given above:

Classification of forests of the United States into forest regions, subregions, and sites—Continued.

THE EASTERN FORESTS—Continued.

Forest region.	Subregion.	Association.	Sites.
Oak—(Con.)..	Oak—shortleaf pine.	....	On dry ridges (north)—shortleaf pine, chestnut oak, scrub and some pitch pine. On dry ridges (south)—shortleaf pine, post oak, black jack oak. On average rolling lands—shortleaf pine, black oak, pignut hickory, Spanish oak, mockernut hickory (lower), chestnut oak (drier and warmer), scarlet oak, black gum (generally scattering), dogwood and persimmon (understory). On low southern situations—shortleaf pine, loblolly pine, red gum, black gum, white oak.
Cypress–tupelo–red gum.	....	River swamps.....	"Sloughs:" Cypress and tupelo. "Glade:" Cypress, tupelo, water ash, willow, cottonwood, white and red bays. "Ridge:" Red gum, slash pine, overcup oak, water oak, hickory, black gum, ash, red maple, honey locust.
		Sour swamps and cypress "ponds."	Poorly drained, highly acid soils. Cypress (*imbricata* or "pond" form), black gum, pond pine, slash pine, sour tupelo, southern white cedar, white and red bays.
		River bottom forest.	Along the larger streams and deeper narrow valleys in the upper Piedmont sections, the forest consists chiefly of hardwoods, red gum, willow and water oak, ash, shellbark, and other hickories, black and red gums, some yellow poplar and cucumber, persimmon, and dogwood. Shortleaf pine is prominent on the warm, south-facing and drier slopes mixed with black oak and post oaks, pignut and mockernut hickories. Toward the lower or southern margin of this forest formation loblolly pine occurs in increasing importance in mixture with shortleaf and the species belonging to the lower and more moist soils; most important in southeast Arkansas. South of Virginia longleaf pine enters and in central Alabama, northern and western Louisiana, and eastern Texas becomes an important member of the composition.
Longleaf–loblolly–slash pine.	....	Longleaf, slash, and loblolly pines.	On low marshy lands in the vicinity of the Gulf and Atlantic coast. Generally flat, with deep sandy soil lacking in humus, alternately very wet and dry. Undergrowth of wire grass and palmetto.
		Pure longleaf pine.	High pine land. This is a belt adjoining low marshy lands in the vicinity of the Gulf and Atlantic coast. Here practically pure stands of longleaf pine cover the sandy hills and plains, while the moist depressions bordering the creeks and streams are occupied by hardwoods, loblolly pine, and cypress. Broom sedge, turkey oak (*Q. catesbaei*), and bluejack oak (*Q. cinerea*) form the undergrowth.
		Longleaf pine in mixture with shortleaf and loblolly pines and hardwoods.	A broken and hilly country lying still farther inland from the coast. Here the longleaf pine mingles with shortleaf pine forests and mixed hardwoods of the uplands.
Mangrove....	....	....	Southern shores of Florida, overflowed generally by salt tidewater. Representative of the tropical forest vegetation.

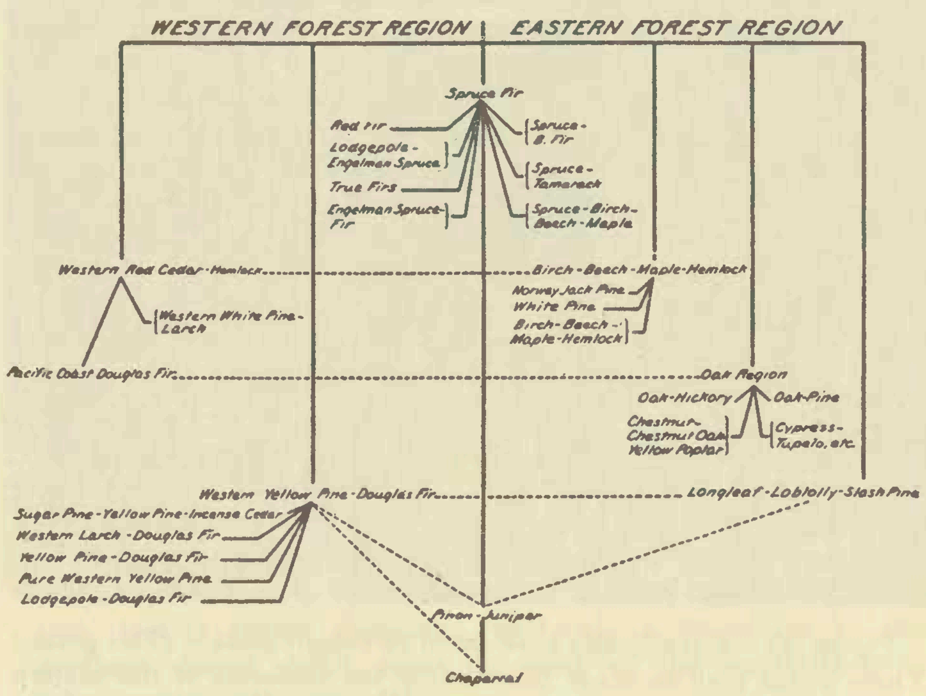


Figure 26.—Diagram showing points of similarity between the forests of the western and eastern parts of the country and the relationships of the different forests.

GRASSLAND VEGETATION.

The central grassland area may be divided into the tall grass (prairie grassland), lying for the most part east of the one hundredth meridian, the short grass (plains grassland) which lies to the west of this line, the mesquite grass (desert grassland), which lies south of the short grass and occupies much of the higher land of west Texas and the lower southern parts of New Mexico and Arizona, and the mesquite and desert grass savanna, which extends across Texas from the Red River southward to the Gulf of Mexico. Bunch grass (Pacific grassland) occurs on the higher plateaus and foothills of eastern Washington, Oregon, and western Idaho, also on the foothills and in the mountain valleys of California and Utah. The short grass extends on the south into the highlands of New Mexico and Arizona, while isolated areas of tall grass occur in east central Texas, the coast regions of Texas and Louisiana, and in portions of Mississippi, Alabama, and Florida. (Fig. 2.)

In addition to these types of grassland, the areas above timber-line on the high mountains of the Cascade-Sierra and Rocky Mountain ranges are occupied by alpine meadows, characterized by low grasses and sedges and a rich admixture of showy-flowered herbaceous plants.

On low, undrained land over which water stands to a depth of several inches during most of the year, such as is found in relatively restricted areas near the Gulf and Atlantic coasts and in Oregon and California, another type of grassland occurs which may be called marsh grassland. It is characterized by coarse, tall grasses, sedges, and rushes, and is often marked in Oregon and along the Gulf and Atlantic coasts by alkali or salt-water plants.

Although all of these areas are characterized by grassy plants, the species, the biological forms, and the conditions of climate and soil are quite distinct.

The short grass characteristic of the high plains develops in a region of early spring and summer rainfall. The average annual precipitation ranges from 12 to 22 inches. The moisture during ordinary years does not penetrate more than 2 feet below the surface. This enables the grasses to grow only a comparatively short time following rains, and they then pass into a drought rest period, which is relatively long in the south and short in the north. Often they do not fruit during the whole summer because of drought. The tall grass and the short grass are distinct in habit of growth, both in height of plant and depth of root penetration, although the latter is largely a response to the soil-moisture conditions, since even the short

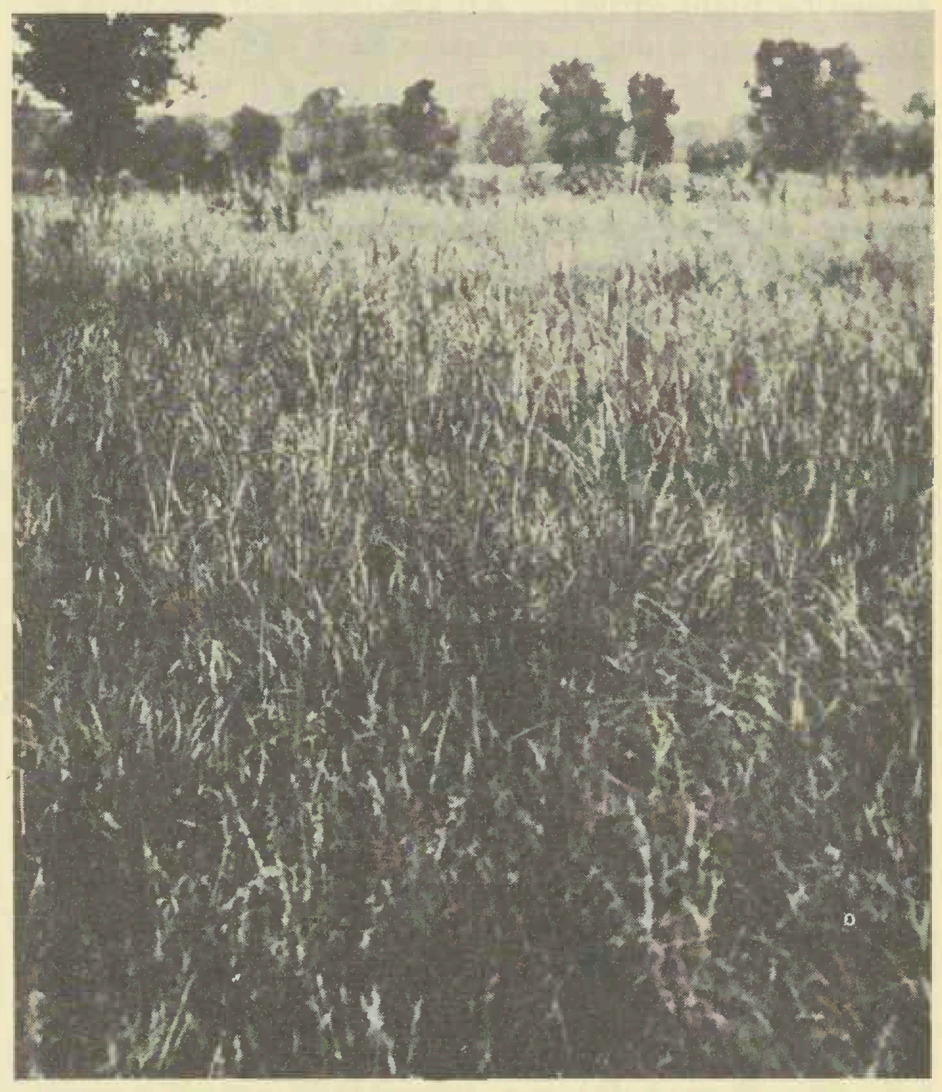


Figure 27.—A bluestem sod characteristic of the great prairie grass region of Illinois, Iowa, and Missouri. (Tall grass.) Bluestem predominates. In spring great quantities of flowers are produced, especially shooting stars, phloxes, violets, and spiderworts, which later are not pronounced features of the grass cover. This vegetation is characteristic of a rich soil, and the land has proven most valuable for agricultural use. Savanna, Ill. Photographed by H. C. Sampson.

grasses will penetrate to great depths if the soil is moist. The tall grasses grow in a region where the soil moisture is distributed to a depth of 2 feet or more. Their growth, as a rule, is not limited by deficient moisture supply, as is usually the case with short grass. The line of demarcation between the tall grass and the short grass is not distinct, since the change in climatic conditions is very gradual, due to the absence of a definite topographic division between the two. A series of wet years will swing the apparent division line westward and a series of dry years will swing it eastward. Notwithstanding the gradual change from one type to the other, these types represent widely different climatic, soil, and soil-moisture relations, and the agricultural significance of the two is quite distinct. It is chiefly a matter of moisture supply; but this is influenced by the conditions favoring water loss and by the permeability of the soil. The tall grass pushes farther west on sandy soil, while the hard lands favor the eastern extension of the short grasses. Heavy grazing also favors the eastern extension of the short grass.

The division line between the short grass and tall grass corresponds to rather sharp soil differences. It is correlated with the depth below the surface of the layer of carbonate accumulation which marks the depth of the periodically moist layer of surface soil. Below this layer of carbonate accumulation the soil is permanently dry except during occasional years of unusually heavy rainfall. Where the depth of moist soil is less than 2 feet, the short-grass type of vegetation predominates. Where greater than about 30 inches, or where lacking entirely, the prairie type of grassland

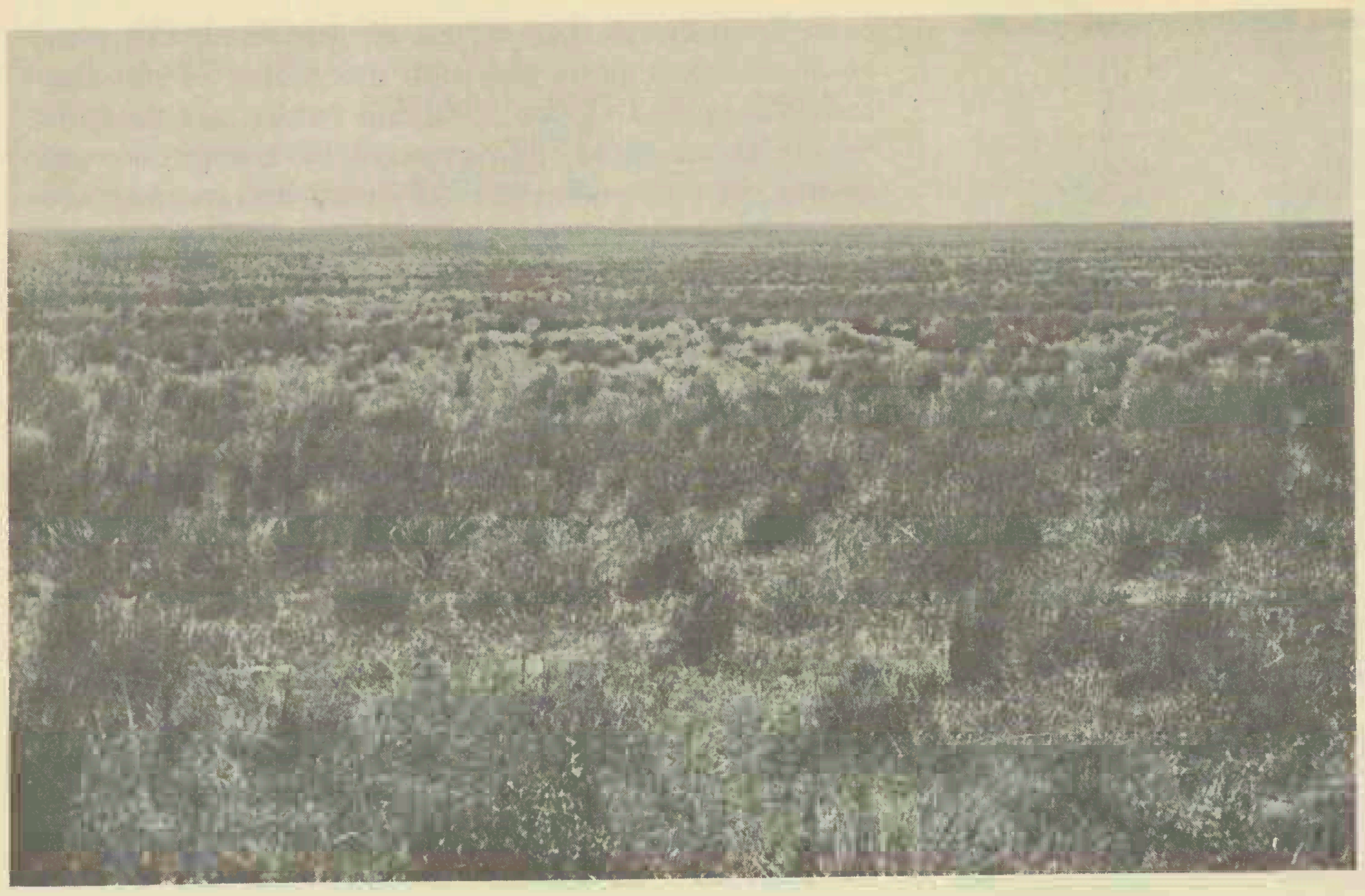


Figure 28.—A scattered growth of bluestem bunch-grass with a variety of other plants occupying the interspaces. (Tall grass.) The western extension of this grassland occurs on sandy land, while farther east it occupies loam soils. It covers most of the sandhills lying within the plains grassland area. There is less available moisture than on the bluestem sod. Bluestem bunch-grass is intermediate between the bluestem sod and the wire grass farther west. When the soil is not too sandy, bunch-grass land has proven valuable for winter-wheat production. Cope, Colo.

Figure 29.—A dense growth of grasses, principally needle grass and slender wheat grass. (Tall grass.) Many herbaceous plants develop among the grasses, and at times this type presents a much more varied appearance than is here shown. In the eastern portion of the area the Andropogons are more abundant. This vegetation has been plowed up in large part and the land used for the production of spring wheat and other crops. The type is characteristic of excellent agricultural land, especially adapted to small-grain crops. Edgeley, N. Dakota. See note to Fig. 7.

occurs. The important point here is the depth of soil periodically moistened by rainfall and the total moisture supply available. Short grass characterizes areas where each season all available soil moisture is consumed by plant growth. All available soil moisture is also consumed along the western edge of the tall-grass formation. Over the tall-grass area as a whole, however, moisture during the rainy period penetrates so deep into the soil that it is not all recovered and brought to the surface by the plants. Consequently the carbonates are carried down or entirely away with the drainage water.

By far the sharpest soil boundary line, that of the disappearance of the layer of carbonate accumulation in the subsoil, lies well within the area characterized as prairie grassland. This soil boundary corresponds in a general way with the eastern boundary of the needle-grass and slender wheat-grass association and the Bluestem bunch-grass association. East of this line the moisture penetrates below the reach of plant roots. Under these conditions there is no dry subsoil between the moist surface soil and the water table. The soil moisture supply is great enough to support a tree vegetation, but on account of the drought of the autumn and late summer, grass fires have swept the area and destroyed the young trees as rapidly as they were produced. Farther west, where the moisture penetration extends to a few feet only in depth, where the subsoil is permanently dry and there is a distinct accumulation of carbonates at a depth varying from 2 to 4 feet below the soil surface, the tall grasses still find sufficient moisture to maintain themselves. This is a true grassland, probably not dependent on prairie fire for its maintenance. To the west the depth of soil moisture becomes less than 2 feet and the tall grasses disappear because of insufficient moisture supply. This is due directly to decreased rainfall and indirectly to the competition of the short grasses. In general, the short grass grows on a shallow soil with a layer of carbonate accumulation at a depth of 1 to 2 feet. The vegetation boundary between the tall-grass and the short-grass formation is of great agricultural importance, since it separates the highly productive farm lands of the prairies from the less productive ranch lands of the plains, except where it swings west around sand hills.

The mesquite grassland differs from the tall grass in having, like the short grass, a deficient moisture supply. Unlike the short grass, however, it is limited to a much warmer climate and for the most part receives its moisture supply from late summer rains. In other words, the short grass farther north usually starts growth in the spring as soon as temperature conditions are favorable. The rains generally come before that period. The mesquite grass, on the other hand, usually passes through a long, dry, hot rest period and begins growth as a result of summer rains. The mesquite and desert grass savanna is similar to the mesquite grass area, but has a higher rainfall and a deeper layer of periodically moistened soil.

The bunch grass develops in a region of deficient moisture supply, but in a region where there is considerable storage of water in the soil during the winter rest period. This is the chief difference between the bunch-grass and short-grass regions. Both pass into a drought rest period much earlier in the summer than the tall grass. With increased summer rain this region would become tall grass; with decreased summer rain, sagebrush; and with decreased winter rain and a slight increase in summer rain, short grass.

The alpine meadows contrast sharply with the tall and short grass types in length of growth season, which here is determined by temperature alone, and not by moisture conditions. Even during the growing season the temperature is low and the supply of moisture sufficient to maintain continuous growth.

The marsh grass is supplied with an abundance of water during the greater part or all of the year.

The growth period of the alpine meadows and the marsh grass, and to a great extent the tall grass, is determined by temperature, the desert grassland by moisture supply, and the short grass by both temperature and moisture supply. The tall grass and marsh grass have relatively long periods of growth, the short grass, mesquite grass, and alpine meadow relatively short growth periods.

Grassland areas of limited extent occur within the boundaries of the forest and desert shrub types. In the north desert shrub wild rye (*Elymus condensatus*) often forms continuous grasslands along the river bottoms. It forms a dense cover of large bunches 4 to 5 feet high and occupies unusually good agricultural land. In the southern desert area Sacaton (*Sporobolus wrightii*) occupies a similar position. Salt grass (*Distichlis spicata*) and tussock grass (*Sporobolus airoides*) will be discussed under the heading *Salt Desert Shrub*.

Figure 30.—A practically pure stand of slough grass. (Tall grass.) These sedge prairies occur on much of the lowlands of the eastern prairie region and are composed of sedges, rushes, water grasses, and an admixture of semiswampy herbaceous water plants. Savanna, Ill. Photographed by H. C. Sampson.

The grasslands of the United States may be divided, therefore, into seven general types:

Tall grass, or prairie grassland.
Bunch grass, or Pacific grassland.
Short grass, or plains grassland.
Mesquite grass, or desert grassland.
Mesquite and desert grass, or desert savanna.
Marsh grass, or marsh grassland.
Alpine meadow, or alpine grassland.

TALL GRASS (PRAIRIE GRASSLAND).

Tall grass (figs. 27 to 30) characterized the great prairie region of the Mississippi Valley and the small isolated prairies through the eastern part of the United States and along the Gulf coast. The area was dominated by tall, luxuriant, and relatively deep rooted grasses. With these grasses were found a large variety of herbaceous flowering plants. The prairie was one of the most distinctive features noted by the emigrants the West. During the spring growing period the crossing from the East to the mountainous regions of prairie had the appearance of a veritable flower garden, composed of phloxes, shooting stars, violets, spiderworts, and other showy plants, almost to the exclusion of the more important but slower growing and less highly colored grasses.

This original vegetation has now been almost entirely replaced by cultivated crops.

Over much of the area the moisture supply comes largely during the growing period and varies from about 20 to 40 inches. The soil moisture extends to a depth of several feet in the drier portions and to ground water in the moister sections. Over most of the area the subsoil is permanently moist, but along the western edge the subsoil is permanently dry and the soil is moistened only to a depth of from 2 to 4 feet. During late summer and fall the moisture supply within reach of the grass roots is often entirely exhausted by the luxuriant growth of grasses, and droughts occur. During drought periods the area has in the past been repeatedly burned by fires started either by Indians, travelers, or lightning. The wet prairies, or sedge prairies, because of their low, swampy character, poor drainage, and aeration, have remained treeless. These grassland areas were often burned over in late summer or winter, and fires have doubtless been a factor in preventing forest growth on adjacent land. In many places fires in the forests themselves have destroyed the trees and enabled the grasses to establish themselves. In the eastern portion of the area fires have in all probability protected the grassland from the encroachment of the forests. Aided by high winds, these fires swept with great rapidity across the grasslands of the prairies and plains, and early settlers and travelers could find safety only by starting back fires, since the broad band of burning grass, often 100 or 200 yards across, made it impossible to pass through the flames to the burnt areas of safety behind. Trees and shrubs are killed by fires, and as a consequence the grasses are able to maintain themselves on land which would support a good forest growth if the trees were adequately protected. Since the settlement of these lands and the consequent checking of the prairie fires, tree growth has been gradually extended, either by planting or natural seeding, and trees now grow throughout the whole prairie region.

Within the area covered by this type of vegetation lies the most valuable body of agricultural land in the United States (fig. 4). The Corn Belt lies largely within this area, in Illinois, Iowa, eastern Nebraska, Kansas, and Missouri. Cotton is produced without fertilizers on the prairies of Texas and southern Oklahoma. Winter wheat is a most important crop in the west central portion of the prairie area. Spring wheat production is confined largely to the prairies of North Dakota, South Dakota, and Minnesota. Barley is produced in large quantities on the prairies of North Dakota, South Dakota, Minnesota, and Iowa, and oats on the prairies of Illinois, Iowa, Minnesota, eastern North Dakota, South Dakota, and Nebraska, and also in the prairie sections of Missouri, Oklahoma, and Texas. Flax culture is most important on the prairies of North

Figure 31.—A sod cover formed largely by wheat grass and little bunch-grass. (Bunch-grass.) A profusion of coarse plants, such as gentians, composites, and umbellifers give a varied appearance to this grassland. Wheat fields are shown in the background. Pullman, Wash.

Figure 32.—An open bunch-grass cover characterized by wheat grass. (Bunch grass.) Many plants from both the wheat-grass sod and the adjacent desert shrub occur in this vegetation. Conditions are more adverse in the bunch grass than in the sod. Near Pendleton, Oreg.

and South Dakota and Minnesota; and although the center of production of timothy and clover hay lies farther eastward, great quantities are also produced in the eastern portion of this prairie area. This region also produces great quantities of wild prairie hay. Alfalfa grown without irrigation is confined largely to the prairies of Kansas, Nebraska, and Oklahoma. The coastal prairies of Texas and Louisiana produce most of the rice grown in the United States.

The tall grass vegetation may be subdivided into the following communities (fig. 3). In the following sections the communities discussed in the larger type are true climax and are known as associations; those in smaller type are developmental for the most part and are associes.

Bluestem sod grass.
Bluestem bunch grass.
Needle grass–slender wheat grass.
Sedge prairie.
Sand sage-sand grass.
Shinnery.
Broom sedge-water grass.

Bluestem sod grass (fig. 27).—This is the most extensive of any of the tall-grass divisions. It occurs over the greater portion of Illinois, Iowa, and eastern Kansas, and also in Missouri, Oklahoma, and Texas, and in western Minnesota and eastern North Dakota, South Dakota, and Nebraska. (Fig. 3.) The prominent grasses are bluestem (*Andropogon furcatus*), bunch grass (*Andropogon scoparius*), and Indian grass (*Sorghastrum nutans*), accompanied by other species. With these grasses there occur at times a great profusion of flowering plants. Of this type was the great prairie of the Mississippi Valley, in crossing which explorers traveled for many days through luxuriant fields of grass.

Over this area the soil is unusually rich, of good texture, and dark color, the result of its high humus content. The surface soil within the reach of the deep-rooted grasses is dried out each year, but the subsoil is permanently moist. The rainfall of 20 to 40 inches comes largely in early spring and summer. In late summer and fall occur droughts, which were doubtless largely responsible for the destructive prairie fires of the region. These droughts were probably as much the result of the luxuriant growth and consequent rapid expenditure of moisture as the lack of rainfall. Much of the best agricultural land of the United States was formerly covered by this type of vegetation (fig. 4). The central portion of this area includes a large part of what is now generally known agriculturally as the Corn Belt.

Bluestem bunch grass (fig. 28).—In passing westward the moisture supply becomes more deficient and plants assume the bunch habit of growth. In central Kansas and Oklahoma (fig. 3) this type is made up largely of bunch grass (*Andropogon scoparius*), together with grasses of the bluestem sod type and a slight admixture of the short grasses of the plains. In appearance this type is more varied than the bluestem sod and presents an open mixed cover. The type extends along the boundary line of short and tall grasses from Nebraska to Texas, and occurs as isolated areas farther west on sand lands and stony open ground. In places bunch grass is practically pure, tending to dominate the area. Conditions for general agriculture are not as good in this type as in the bluestem sod, owing principally to the lesser moisture supply. The average annual precipitation is usually 20 to 30 inches. The surface layer of moist soil is from 2 to 4 feet in depth and there is no loss of moisture to the subsoil, which is permanently dry. The greatest winter-wheat areas in the United States lie within the area marked by this vegetation.

Needle grass slender wheat grass (fig. 29).—Farther north, in Nebraska, the Dakotas, and Minnesota (fig. 3), needle grass (*Stipa spartea*) and slender wheat grass (*Agropyron tenerum*) become relatively more important. This type forms a dense sod cover, but the plants are not as vigorous as the bluestem sod grasses farther south. The rainfall is also somewhat less (18 to 30 inches), but at the same time the evaporation is also less. The soil is dark and is moist to a depth of 3 feet or more. The subsoil in much of the area is permanently dry. Here, as in the bluestem sod, herbaceous plants play a prominent rôle. The greatest spring-wheat area in the United States has developed on land characterized by this type of vegetation.

Sedge prairie (fig. 30).—Farther eastward, on the lower swampy, poorly drained lands, wet prairies or sedge prairies become prominent. Their vegetation is made up of sedges, rushes, and coarse grasses, such as bluejoint (*Calamogrostis canadensis*), reed canary grass (*Phalaris arundinacea*), slough grass (*Spartina michauxiana*), sedges, rushes, and semiaquatic herbs. This grassland merges gradually into the true marsh grassland, and is probably treeless because of its swampy condition. It can not be made productive agriculturally without drainage.

Sand sage–sand grass.—At the western edge of the bluestem bunch-grass land and extending out into the short grass, mostly in South Dakota, Nebraska, Colorado, Kansas, and Texas, large sandhill areas occur. These are covered either with bunch-grass or with sand sage–sand grass. The latter varies greatly in appearance. Among the prominent plants are sand sage (*Artemisia filifolia*), sand grass (*Calamovilfa longifolia*), and the grasses of the bluestem bunch-grass type. The moisture supply is even less here than on the bluestem bunch-grass type, but the loose soil and open cover enable plants to continue growing during long periods of drought. The open vegetation cover contains in addition to grass a large number of other plants. The soil is far too light for safe cultivation, owing to the danger of blowing when denuded.

Shinnery.—Similar sand areas in Texas, Oklahoma, and New Mexico are covered with bunch grass assoicated with shin oak (*Quercus havardii*). This oak seldom exceeds 3 feet in height and forms a dense low shrubby growth. This vegetation, locally called shinnery, represents a transition to the southern desert shrub, since on many of the sandhills it is interspersed with mesquite.

Broom sedge–water grass.—Near the Gulf coast, from Texas to Florida, are extensive coastal prairies of broom sedge–water grass, dominated largely by water grass (*Paspalum* sp.), switch grass (*Panicum virgatum*), broom sedges (*Andropogon glomeratus*, *A. saccharoides*), and bluestem (*A. furcatus*), all of which can persist in a wet soil. This vegetation corresponds more nearly to the sedge prairie than to any other and at the lower margin merges almost imperceptibly with the marsh grasslands of the coast. In addition to the grasses many showy flowering plants occur. The rainfall is heavy, ranging from 30 to 60 inches annually. These lands have proven to be valuable for grazing and for cotton and rice culture.

BUNCH GRASS (PACIFIC GRASSLAND).

This grassland is composed of bunch grasses, occurring chiefly in the Western States—California, Oregon, Washington, Idaho, Montana, and Nevada. In Oregon, Washington, and California it occupies extensive areas, and in the Palouse region forms a relatively dense stand. Throughout the northern Great Basin this bunch grass type occurs at higher elevations below the conifer zone. It is characterized by a rich display of flowering plants. The condition under which bunch grass develops is that of a moisture supply insufficient for a dense stand of grasses. The rainfall varies from 10 to 25 inches. Some of the moisture supply comes during the growing season, but at the beginning of the growing season moisture is usually present to a depth of several feet in the soil. If rainfall were confined to the growing period, short grasses would develop, and if a still greater proportion fell during the winter rest period it would give way to sagebrush.

Although this type occurs in Arizona, New Mexico, Colorado, and Utah, it becomes of importance only in Washington, Oregon, and California. In Washington and Oregon it indicates the best wheat land of the Northwest. All of the area is valuable grazing land, and in California especially the bunch grasses have long since disappeared as a result of overgrazing, and only the weed grasses remain. Even in the Northwest the bunch grasses are being rapidly killed out by overgrazing.

The bunch-grass vegetation may be divided into the following communities:

Wheat-grass sod.
Wheat-grass bunch.
Stipa–Poa–bunch grass.

Wheat grass sod (fig. 31).—In the eastern portion of Oregon and Washington (Palouse region) (fig. 3), where the moisture conditions are more favorable, this grass produces a sod which contains, in addition to wheat grass (*Agropyron spicatum*), the little bunch grass (*Festuca idahoensis*), poa (*Poa sandbergii*), and balsam root (*Balsamorrhiza sagittata*). During the early spring and summer this area presents a luxuriant and varied appearance, due largely to the prominence of plants with large, showy flowers and leaves. The rainfall is from 15 to 25 inches. Within the area marked by this type lie the best wheat lands of the Northwest.

Wheat-grass bunch (fig. 32).—In the western portion of the northwest prairie, where the moisture supply is deficient, or the soil less able to hold available water, due to its shallow or rocky character, this plant cover presents an open bunchlike appearance. It is composed of wheat grass (*Agropyron spicatum*) either alone or mixed with poa (*Poa sandbergii*) and conspicuous herbaceous plants. This type marks the transition from the wheat-grass sod to the sagebrush desert. It occurs in areas receiving from 15 to 20 inches of precipitation, and is widely distributed, especially in the northern portion of the Great Basin (fig. 3). It is interesting to compare the behavior of such grasses as wheat grass (*Agropyron spicatum*) and bunch grass (*Agropyron scoparius*). Both are sod formers when sufficiently supplied with water, and both assume the bunch habit under more arid conditions. In both cases the cause is a deficient moisture supply which causes grasses, as well as shrubs and trees, to develop only in open stands. Overgrazing is rapidly reducing this grassland to the weed-grass type discussed below.

Stipa–poa bunch grass (figs. 33 and 34).—The great central valleys of California, the San Joaquin and Sacramento, also the Salinas and other valleys along the west coast, were first settled by the Spaniards and devoted to stock raising. On the arrival of the settlers from the Eastern States the natural vegetation of this area did not differ essentially from its present condition. Along the streams were scattered groves of live oak (*Quercus agrifolia* and *Q. wislizenii*) and valley oak (*Quercus lobata*), and the areas between were occu-

Figure 33.—California needle grass on land protected from grazing. (Bunch-grass.) This open stand of perennial bunch grasses probably represents the original grassland of the central valleys of California. It is very similar to the bunch-grass vegetation of Oregon and Washington, which is also giving way as a result of overgrazing to introduced annual grasses. For this reason the California grassland has been included with the grasslands of Oregon and Washington in the bunch-grass division. Perris, Calif.

Figure 34.—A luxuriant growth of annual brome grasses (chiefly Bromus rubens). (Bunch-grass.) Wild oats and filarees are often important. Growth usually takes place in the winter or early spring, and the plants soon ripen seeds and remain as a dry dead cover throughout the remainder of the year. Porterville, Calif. Photographed by A. W. Sampson.

pied by weedy vegetation consisting largely of annual brome grasses (*Bromus rubens*, *B. hordeaceus*, *B. tectorum*), filaree (*Erodium cicutarium*), wild oats (*Avena fatua* and *A. barbata*), fox tail (*Hordeum murinum*), bur clover (*Medicago hispida*), and many other weedy plants (fig. 34). The wheat-grass bunch type of Oregon and Washington is being reduced to this weedy condition where the original grasses are entirely killed out by overgrazing. Such seems to have been the history of the California grassland, and perennial grasses persist in sheltered or protected areas. These are chiefly California poa (*Poa scabrella*) and California needle grass (*Stipa pulchra*) (fig. 33), which seem to represent the original plant cover. The stages in the reduction of this bunch-grass type to the present weed-grass type is not yet known to science. E. O. Wooton has recently observed the following stages, which the sheepmen of the region confirm: The original (1) bunch-grasses, lupines, clovers, and borages gradually give way as a result of overgrazing, to (2) wild oats and bur clover, and these in turn to (3) filaree, (4) fox tail, and finally to (5) red brome (fig. 34). At present this grassland is characterized largely by weedy annuals. Following the winter rains these short-lived grasses produce a luxuriant carpet, dotted by many showy flowering plants such as California poppy (*Eschscholzia californía*). The vegetation matures early and remains during a long summer rest period in a dried condition. The winter rains cause the seeds to germinate, producing the later winter and early spring growth.

Land in this area, when irrigated, is used for alfalfa, rice, and sugar beets, and is good for fruit, including grapes, apricots, and peaches, as well as citrus, figs, and other semitropical fruits. The dry farm lands produce barley and wheat, much of which is cut green for hay.

SHORT GRASS (PLAINS GRASSLAND).

Short grass characterizes the Great Plains lying east of the Rocky Mountains and for the most part west of the one hundredth meridian (fig. 2). The grasses are low-growing (figs. 35–39) and shallow rooted, owing to a low precipitation, 12 inches in north central Montana to 22 inches in western Texas, which falls largely just preceding and during the growing season. In most cases it does not penetrate more than 2 feet before it is exhausted by the grass cover. A layer of carbonate accumulation in the soil at a depth of from 8 to 20 inches marks the depth of the periodically moist surface soil layer. There is no storage of available soil moisture from year to year and the subsoil is permanently dry. The growth of deep-rooted plants, therefore, is not possible. The frost-free period varies from about 100 to 200 days, but the growth season of the short grasses seldom exceeds 90 days. Grama grass, which is more characteristic of the north, requires about 100 days to complete its growth and produce seed, while buffalo grass, which is limited to the south, has a much shorter growing season of about 40 days. Moisture is the limiting factor, and the buffalo grass in Colorado may bloom either in June or August, depending upon the distribution of the moisture supply. During dry years this great expanse presents the appearance of an endless carpet, while in wet years taller plants develop on the short-grass sod and give to it a more mixed appearance.

Dry farming has been undertaken in nearly all parts of the short-grass region, but it has proven profitable only in the less arid portions. Under irrigation the soil generally is productive and has been most successfully employed in growing cereals, alfalfa, sugar beets, potatoes, and other vegetables. This region is not thickly settled. Although most of the land has been taken up, less than one-eighth was in harvested crops in 1919. Probably nearly a twentieth was crop failure or lying idle or fallow.

In the east-central portion corn is an important crop and is usually grown in rotation with winter wheat. Spring wheat is grown in North and South Dakota, Montana, northwestern Nebraska, and eastern Wyoming. Of the cereals, wheat, barley, and oats are most successfully grown in the northern portions, while sorghums and corn are the principal crops in the south. In the extreme northern portion flax and potatoes are important. The northern portion is given over more particularly to grain production and the southern portion to coarse forage. The most valuable agricultural land in this section lies in the northern and eastern portions, since drought is more severe in the south and west.

Figure 35.—Western wheat grass on sod composed of buffalo grass and grama grass. (Short grass.) During favorable years it is important as hayland, as shown by the shocks in this picture, but during dry years little or no hay is produced. It is limited largely to the clay, or gumbo, lands of South Dakota and adjacent States. Phillip, S. Dak.

The short-grass vegetation may be subdivided into several associations, including the following:

- Grama grass.
- Grama-mountain sage.
- Grama-Muhlenbergia.
- Galleta grass.
- Grama-buffalo grass.
- Wire grass.
- Western wheat grass.
- Grama-western needle grass.

Grama grass (fig. 36).—The grama-grass area on the west is separated from the mixed grama and western needle grass and grama-buffalo grass areas on the east by a line running near the North Dakota-Montana boundary, cutting west of the Black Hills, and extending down close to the mountains in Colorado. This area also includes the higher valleys in Colorado, New Mexico, Arizona, and isolated spots in Utah (fig. 3). The vegetation is dominated largely by grama grass (*Bouteloua gracilis*, formerly called *B. oligostachya*), which often constitutes an almost pure sod. Prominent spring flowers are the white mountain lily (*Leucocrinum montanum*), pasque flower (*Pulsatilla hirsutissima*), phlox (*Phlox hoodii*), wild onion (*Allium textile*), and ground daisy (*Townsendia exscapa*). Over the northern portion of the area mountain sage (*Artemisia frigida*) is prominently associated with the grass. In Montana and Wyoming grama grass often alternates with the sagebrush type, and is modified by the abundant admixture of nigger wool (*Carex filifolia*) and June grass (*Koeleria cristata*). In the south, in Colorado, Texas, and New Mexico, where the soil is rocky or where the short grasses have been damaged by overgrazing, it is often modified by an admixture of match weed (*Gutierrezia sarothrae* and several allied species). The grama-grass type marks the portion of the short-grass area which has the lowest evaporation and the coolest, shortest season, but which has a relatively low rainfall. This is an important grazing section, and in the northern portion grain farming has developed in many localities.

Grama grass and mountain sage.—Along the mountain front grama grass (*Bouteloua gracilis*) is often mixed with a great variety of plants which are more typical of the mountain grasslands. Among these may be mentioned mountain sage (*Artemisia frigida*), nigger wool (*Carex filifolia*), yarrow (*Achillea millefolium*), Eriogonums of various species, Pentstemons, wild roses, and lupines. These characterize an area in which the rainfall is greater than that of the adjacent grama-grass land. The soils are often not well developed but consist of loose granitic gravels. Where land is level and favorable for cultivation conditions are much better than in the grama-grass area farther east. The small grains, spring wheat, oats, barley, and rye, are the chief crops grown in this area.

Grama grass and Muhlenbergia.—In the southern portion of the grama grass area, especially in Colorado and New Mexico near the mountains, conditions become so extreme as to temperature and drought, that grama grass gives way in part to *Muhlenbergia gracillima*. With this often occurs the cane cactus (*Opuntia arborescens*). This associes characterizes land of inferior production, even as grazing land, and of doubtful value for crop production.

Galleta grass.—The grassland dominated by galleta grass (*Hilaria jamesii*) covers extensive areas in northern New Mexico and Arizona, and pushes far into the Utah desert. The grass forms an open sod cover, often practically pure, and when dormant it usually presents a uniform light-colored appearance. At a distance it can be detected from the winter-fat areas of the northern desert only by the slightly yellow tint of the dried foliage. During a series of dry years it often replaces sagebrush and is in turn replaced by sage during periods of more favorable moisture supply. This community represents the greatest extension of the short-grass land into the Great Basin area. It covers land not unlike that described as sage or rabbit brush land, and can not be distinguished on the basis of moisture relation and alkali content from sage land. It is probably the best grazing land in the southern portion of the northern desert shrub, with the possible exception of areas covered by winter fat.

Grama-buffalo grass (fig. 37).—This type extends over western Nebraska, Kansas and Oklahoma, eastern Colorado and New Mexico, and the Panhandle of Texas (fig. 3), and is dominated by almost equal quantities of grama grass (*Bouteloua gracilis*) and buffalo grass (*Bulbilis dactyloides*). It occurs as a uniform open sod, and is the most typical short grass of the

Figure 36.—A good sod of grama grass and nigger wool, with occasional plants of June grass and western needle grass. (Short grass.) The prominent flowering plants are the wind flower, bitter root, mountain lily, and townsendia. This grassland is most important in Montana and along the western edge of the Great Plains. Over much of this area small grains are grown during normal and favorable years. Glendive, Mont.

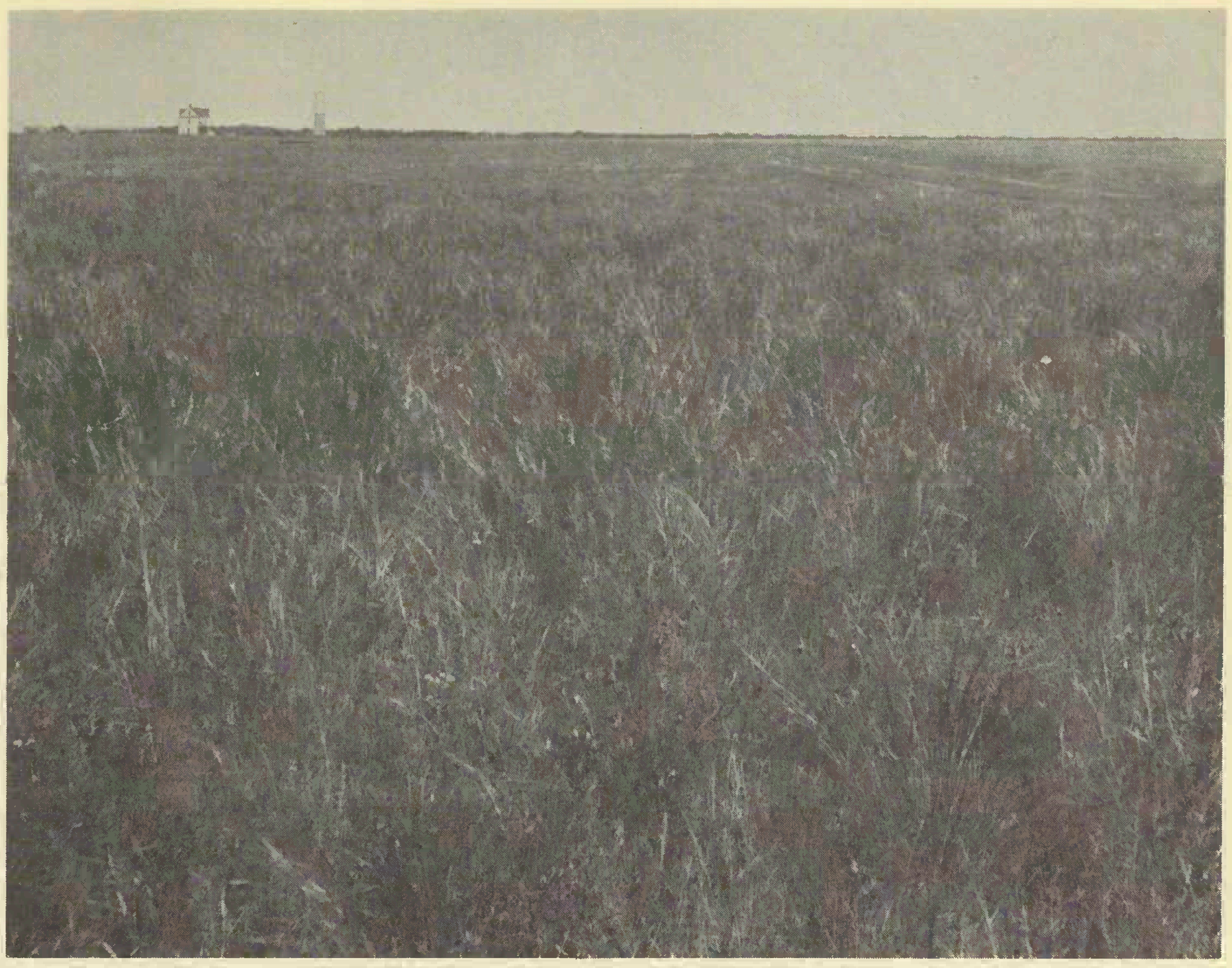


Figure 38.—A close stand of wire grass. (Short grass.) The taller wire grass obscures the grama and buffalo grass which form the bulk of the sod. This grassland lies between the pure short grass on the west and the bluestem bunch-grass on the east. Hays, Kans.

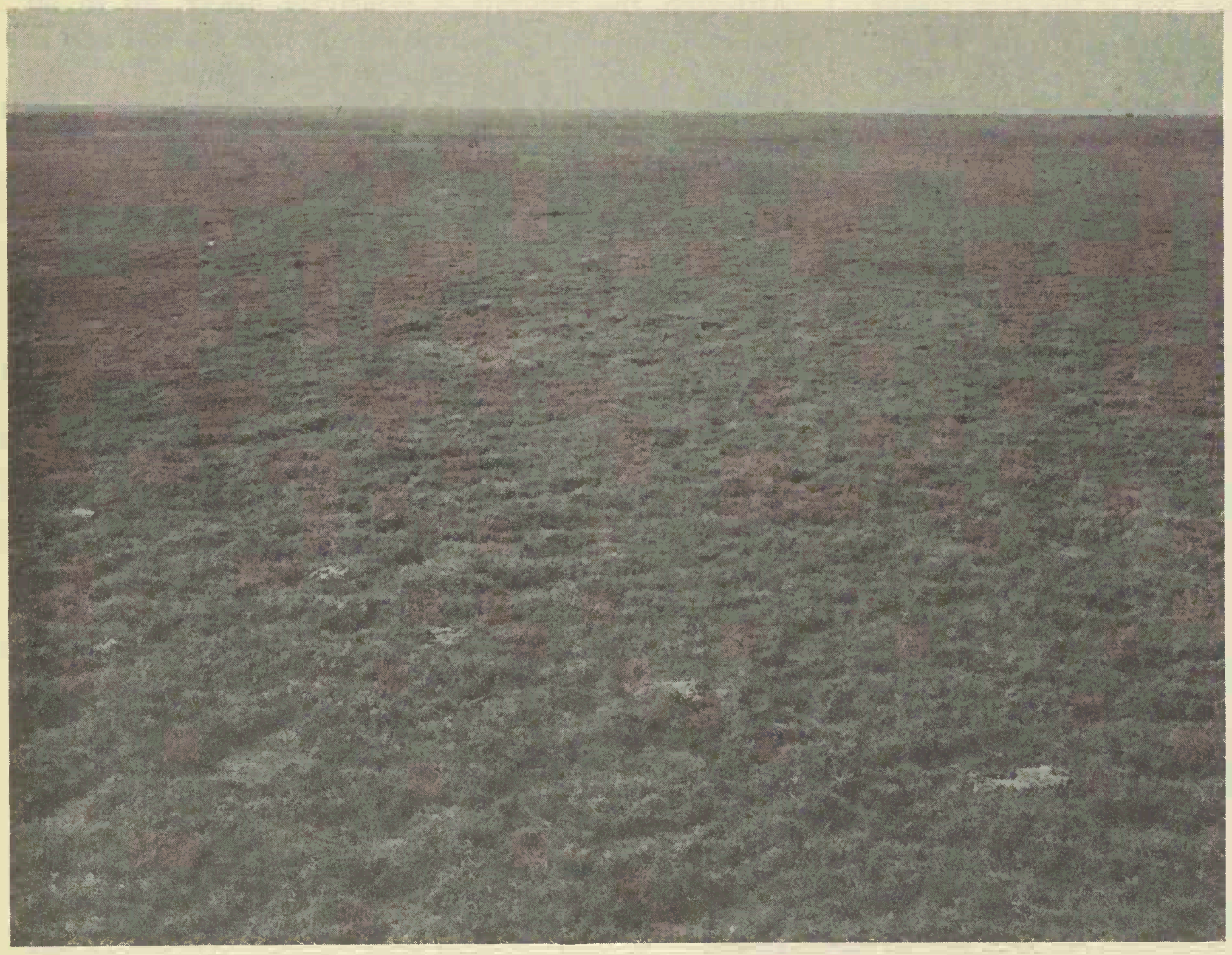


Figure 37.—A pure, even cover of grama and buffalo grass interrupted uniformly by small patches of bare ground. (Short grass.) A pure short-grass cover indicates soil moistened only to a depth of 1 or 2 feet. Akron, Colo.

Figure 39.—A grama grass–western needle grass cover with conspicuous perennials, such as silvery psoralea and purple corn-flower. (Short grass.) This type is intermediate between the needle grass–slender wheat grass of the prairie and the grama grass of the plains. Mandan, N. Dak.

plains grassland. Although many other plants occur in this association, typical areas, except during wet years, appear as a pure open sod. The annuals, including plains plantain (*Plantago purshii*), annual fescue (*Festuca octoflora*), pennyroyal (*Hedeoma hispida*), and beggar's tick (*Lappula occidentalis*), are short-lived and seldom more than an inch or two high, and the perennials are also, for the most part, low-growing plants. During exceptionally wet years weeds, such as horseweed (*Erigeron canadense*) and gumweed (*Grindelia squarrosa*), and taller perennial grasses, such as western needle grass (*Stipa comata*) and sand sporobolus (*Sporobolus cryptandrus*), develop a cover of taller plants. Within this area, especially in the north, the small grains do fairly well in medium or wet years, but fail in dry years. The sorghums and short-season corns also do fairly well. Fall wheat is grown in the northern and eastern portions.

Farther east, where the rainfall is greater, or on lighter land, where moisture penetrates rapidly, tall plants become more abundant. These are chiefly wire-grass (*Aristida longiseta*) and psoralea (*Psoralea tenuiflora*), which indicate conditions somewhat more favorable for crop production than a pure even sod of short grass. Two types, modifications of this, and transitions to the prairie type, are the wire-grass and the wheat-grass types. The soapweed (*Yucca glauca*) is one of the most prominent plants on this type of grassland on the Staked Plains of Texas.

Wire grass (fig. 38).—This type consists of a more or less open cover of grama and buffalo grass with a scattered growth of wire grass (*Aristida longiseta*) and many other deeper-rooted plants, such as psoralea (*Psoralea tenuiflora*), bush morning-glory (*Ipomoea leptophylla*), etc. It forms a belt between the grama-buffalo grass of the plains grassland and the bunch grass of the prairie grassland, and is most extensive in Nebraska, Kansas, and Texas. During wet years the deeper-rooted plants thrive best, but during dry years they often fail to grow. Here the conditions for crop production are more favorable than on the pure grama-buffalo grassland.

Western wheat grass (fig. 35).—This grassland is characterized by an even sod of grama and buffalo grasses and a scattered growth of western wheat grass (*Agropyron smithii*). During favorable years, when the wheat-grass fruits abundantly, prairie hay is cut from this type. It presents a more luxuriant appearance than pure short-grass and produces a heavier crop of forage. As a rule it contains fewer nongrasslike plants, and often occurs as a practically pure cover. This type is distributed over the unusually heavy gumbo soils derived from Fort Pierre shales in South Dakota, Nebraska, and Colorado (fig. 3), and occurs locally over a much wider range. Agriculturally land of this type does not differ greatly from land of the grama–buffalo grass type.

Grama–western needlegrass (fig. 39).—In western North Dakota and portions of South Dakota (fig. 3) grama (*Bouteloua gracilis*), with an admixture of the taller-growing western needlegrass (*Stipa comata*), constitutes a large percentage of the grass cover. The attending moisture conditions are more favorable than under pure grama, and the vegetation is much more varied in appearance. Needlegrass when in fruit is much more noticeable than grama, and the whole area at times looks somewhat like the needlegrass–slender wheat grass of Minnesota. This type is intermediate between the grama of the plains grassland and the needlegrass–slender wheat grass of the prairie grassland. Many plants from both the short grass and the tall grass areas are found here. Purple cone-flower (*Echinacea angustifolia*), silvery psorale (*Psoralea argophylla*), and June grass (*Koeleria cristata*) are the most prominent plants, with the exception of the dominant grasses. Under cultivation land characterized by this type is more productive than any other short-grass type.

MESQUITE GRASS (DESERT GRASSLAND).

This grassland occurs in Texas, New Mexico, and Arizona and extends southward far into Mexico (fig. 3). It is characterized by a growth not conspicuously different (figs. 40 to 42) from the short grass of the plains. The growth period in this grassland does not begin in the spring as in the plains grassland, but as a result of summer rains in July or August, which start the drought-dormant perennial grasses into growth. The evaporation is excessive, the temperature high, and the annual rainfall low, ranging from 12 to 18 inches. The grass cover is usually even and more open than the short grass, and the soil-moisture supply is usually utilized soon after the rainfall. Growth is relatively rapid and the grasses soon become dry in places. In this condition they furnish excellent forage. On most of this land the conditions for dry farming are not as good as on the short-grass land. The dry, hot summer, with the growth period limited to the hotter months of July, August, and September, restricts dry-land production to the sorghums and similar warm-weather crops, and assures the almost certain failure of small grains. Areas of pure grassland are not great in extent, and much of the surface is covered by scattered desert shrubs such as mesquite, creosote bush, yuccas, black brush, and cat's claw. The Emory oak of the chaparral type (*Quercus emoryi*) often occurs on the grassland, forming open savannas.

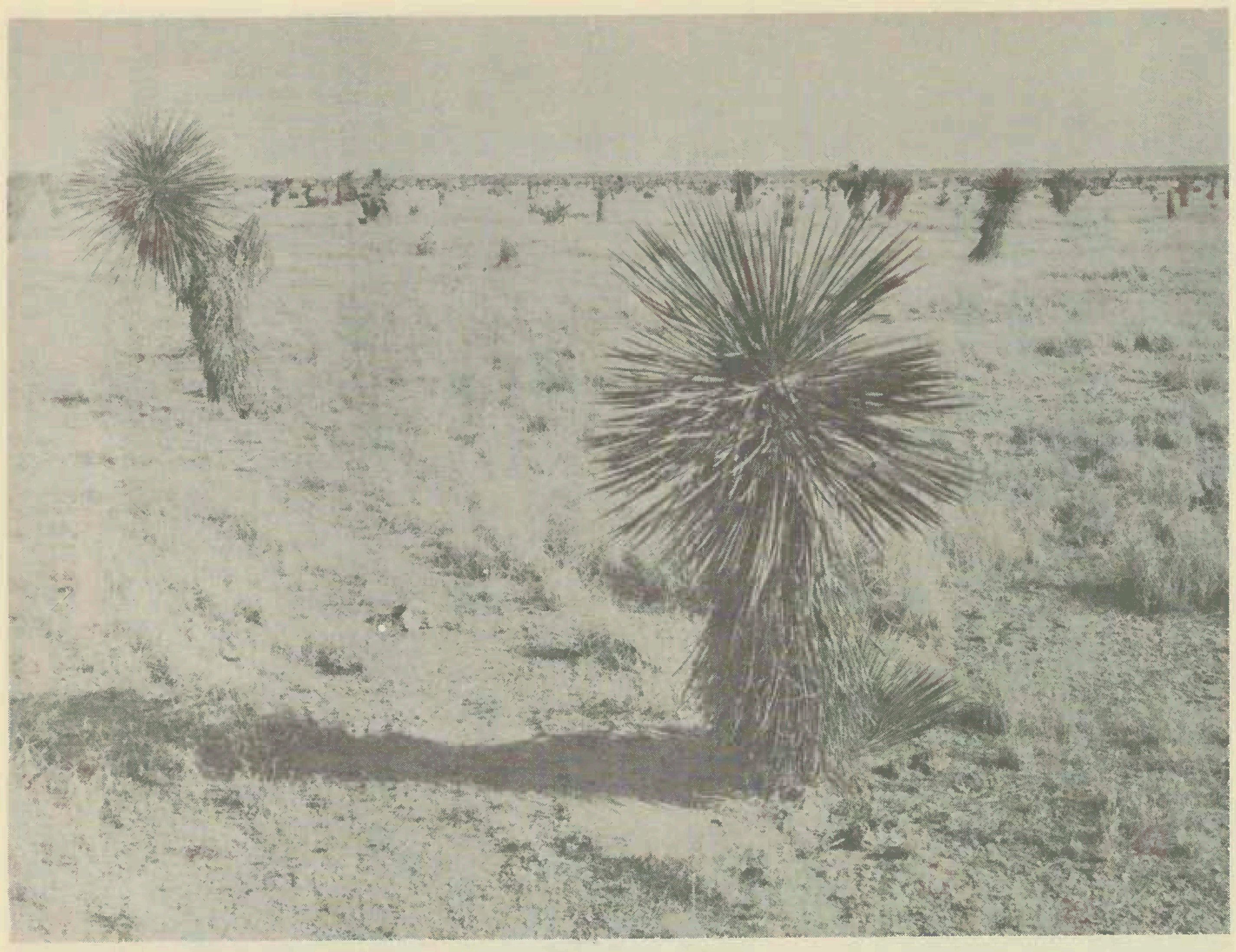


Figure 40.—Black grama, tobosa grass, and yucca. (Mesquite grass.) This grassland is either pure or has scattered plants of yucca, mesquite, or creosote bush. Moisture conditions are very adverse. The growth period commences after the summer rains and continues until checked by drought. Northwest of Hope, N. Mex.

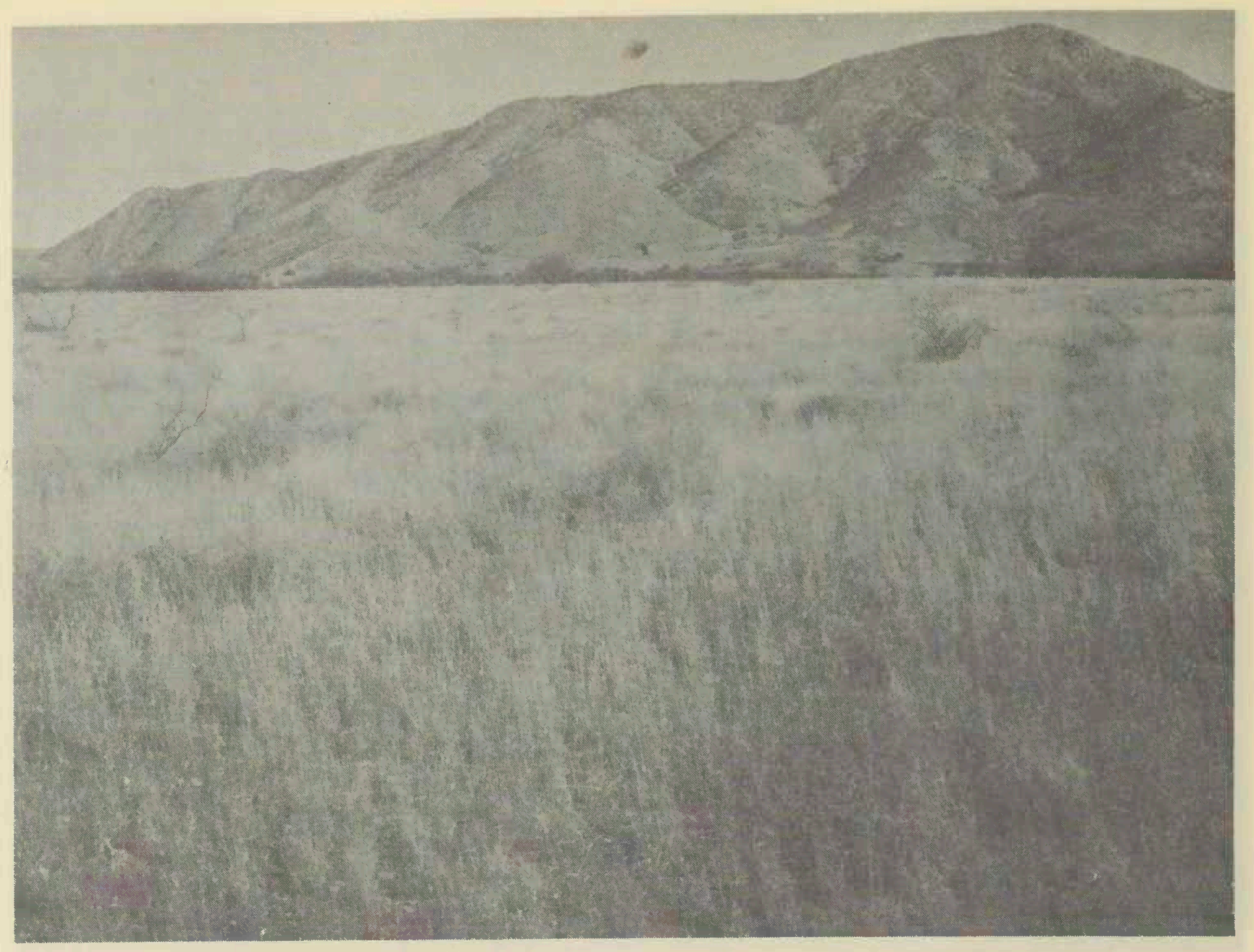


Figure 41.—Crowfoot and six-weeks grama grass. (Mesquite grass.) The appearance is that of a short crop of cereal. Growth is rapid and follows summer rains. The grass is soon cured in place by drought and forms excellent pasture. Santa Rita, N. Mex.

This grassland may be subdivided as follows:

Black grama.
Crowfoot grama.
Curly mesquite.
Tobosa grass.

Black grama (fig. 40).—The most extensive community is that of the black grama (*Bouteloua eriopoda*). It seldom occurs as an unmixed grassland, but over its surface are usually scattered yucca (*Yucca elata*), mesquite, creosote bush, black brush, or cat's claw. It occupies most of the sandy or gravelly slopes lying between the river bottoms and the foothills in New Mexico, and it is common in Texas and Arizona (fig. 3). It does not form a close sod, but a relatively open grass cover.

Crowfoot grama (fig. 41.)—In southeastern Arizona (fig. 3) crowfoot grama (*Bouteloua rothrockii*) characterizes the greater portion of the grassland. This plant is erect in growth, and it forms an even stand which during good years can often be cut for hay. It is often associated with other species of *Bouteloua* and *Aristida*. Areas occupied by this type are often free of shrubby growth, but for the most part the mesquite, cat's claw, and chollas from the adjacent deserts occur on these grasslands. On eroded or overgrazed areas six-weeks needle-grass (*Aristida adscensionis*) and six-weeks grama (*Bouteloua aristidoides*) are prominent. Like black grama, the crowfoot grama is excellent forage.

Curly mesquite.—Curly mesquite (*Hilaria belangeri*) forms a close sod grassland in southeastern Arizona, which resembles very closely the buffalo-grama sod of the high plains. It occurs over rolling country at rather high elevations and is often accompanied at the upper elevations by scattered oaks (*Quercus emoryi*). This is excellent grazing land. In Texas this type is almost always marked by scattered trees of mesquite, opuntia and other plants. The grass cover is somewhat more mixed in this section and is often composed partly of buffalo grass (*Bulbilis dactyloides*) and a number of other grasses, chiefly species of *Aristida* and *Bouteloua*.

Figure 42.—A curly mesquite-grass sod with an occasional tree of mesquite and cholla. (Desert savanna.) This grassland in general aspect is somewhat similar to the short grass of the plains. The grasses subsist on the moisture stored in the surface soils, while the trees draw their moisture supply largely from the sub soil. The grasses are chiefly curly mesquite with aristidas and gramas. Big Springs, Tex. Photographed by A. J. Olmstead.

Tobosa grass.—Tobosa grass (*Hilaria mutica*) occurs throughout the range of the desert grassland and marks the heavy or impervious soils, especially in depressions where drainage water stands after a rain. It occupies extensive areas at the bottoms of the basins and in distribution can be separated with difficulty from the desert shrub.

While green it is regarded as good forage, but the plants soon become dry and woody. False needle grass (*Scleropogon brevifolius*) is often abundant in tobosa-grass areas.

MESQUITE AND DESERT-GRASS (DESERT SAVANNA).

This type consists of a short-grass cover over which are scattered small trees or thorn bushes. Both the beginning and the end of the growth period are usually determined by available moisture. Temperature plays almost no part in limiting the growth of the natural vegetation. The distribution of water throughout the season is somewhat similar to that in the desert region. The rainfall is relatively heavy, but the high temperatures and the high-saturation deficit of the air subject the plants to extreme drought conditions. There is a tendency over much of the area for the greatest rainfall to come in the spring and summer, during the period of greatest growth. Portions of the area have a rainfall of less than 20 inches, but in the east it runs to as high as 30 inches. The evaporation rate is high.

This savanna occurs in Texas south of the Red River and mostly south and east of the Plains border. (Figs. 2 and 3.) It also extends over the lower southwest portion of the high plains in Texas.

Two divisions may be recognized within the area here considered: The thorn-bush and mesquite-grass associes and the mesquite and mesquite-grass association. In the western portion the mesquite trees are small, and there are many other small thorny trees and bushes which occur at intervals over an open grass cover. Much of the land is rough and broken and the vegetation partly in a developmental stage. This area may be designated the thorn-bush and mesquite-grass associes. Farther east the rainfall is heavier, the trees larger, and the grass cover much denser. This type may be distinguished as the mesquite and mesquite-grass association.

Mesquite and mesquite grass (fig. 42).—Mesquite and mesquite grass constitute one of the most distinctive types of Texas vegetation. The trees may be either scattered or close together to form an open forest. They often give the appearance of an orchard of small fruit trees. Mesquite (*Prosopis juliflora*) is the dominant tree, although others occur. In many places, especially in the south, prickly pear (*Opuntia lindheimeri*) is almost as plentiful as mesquite. Grasses are abundant, chiefly curly mesquite (*Hilaria belangeri*), buffalo grass (*Bulbilis dactyloides*), and species of Aristida and Bouteloua. Mesquite is often damaged by drought.

In general appearance this association suggests an abundant water supply, followed by extreme drought. The soil is not deep, the layer of carbonate accumulation occurring, in general, at a depth of 1½ to 2½ feet. Although the rainfall is relatively heavy, 20 to 30 inches, it does not penetrate deeply into the soil and is rapidly absorbed and transpired by the growing plants.

This association forms a band about 150 miles wide extending from the Gulf of Mexico on the south to the Red River on the north. This band in the central portion is bent westward to Martin County, Tex. The larger mesquite trees and much denser grass cover distinguish this association from the thorn-bush and mesquite-grass associes. This is because the available moisture is greater in the mesquite and mesquite-grass area. On the north mesquite is apparently limited by low temperatures and on the east by the oak forests. Mesquite here grows on a dark soil with a layer of lime accumulation at about 2½ feet. The oaks grow on sandier land of lighter color where the zone of carbonate accumulation has disappeared.

This area is suitable for grazing and the mesquite trees furnish both fence posts and firewood. Much of this land has been put under cultivation. Cotton is the principal crop, although grain sorghums are important, especially in the north, and corn throughout the area.

Thorn-bush and mesquite grass.—In the thorn-bush and mesquite grass associes thorn bushes and cacti, as well as mesquite, are scattered over a sparse desert-grass cover. The soil is always visible because of the sparse vegetation.

The cover in this association is composed of curly mesquite grass (*Hilaria belangeri*), buffalo grass (*Bulbilis dactyloides*), species of Aristida, and other desert grasses. Small mesquite trees (*Prosopius juliflora*) are scattered over this grass cover, and with these are associated thorn bushes and cacti of various types.

This associes extends in a narrow strip from the Gulf of Mexico near the mouth of the Rio Grande River northwest to the southeast corner of New Mexico and across and up the southeast border of the high plains into Cottle and Motley Counties, Tex. On the western edge this type passes either into southern desert shrub, in which case the grasses disappear and a shrubby, open growth takes its place, or into desert grassland, in which case the trees and shrubs disappear, leaving the grasses dominant.

The high water requirement in this hot climate and the long drought period make this type of doubtful agricultural value. Attempts have been made to grow cotton and grain sorghums in the better portions.

MARSH GRASS (MARSH GRASSLAND).

Marsh grassland occurs in scattered areas in many portions of the United States. The most important areas occur in the central valleys of California, along the Gulf and Atlantic coasts, and in the Everglades of Florida. (Figs. 2 and 3.) They may be classified roughly into salt marsh and fresh marsh. For the most part the salt marsh lies along the coast, although in Oregon and California the inland marshes are often developed in alkali areas and a sharp distinction between salt and fresh marshes can not be made. The fresh marshes are characterized largely by Indian rice (*Zizania aquatica* and *Z. palustris*), cat tail (*Typha latifolia*), and tule (*Scirpus validus*) (fig. 44), and in Florida by saw grass (*Cladium jamaicense*) (fig. 43); while the salt marshes are marked by marsh grass (*Spartina alternifolia* and *S. patens*) along the coast. The principal places where marsh-grass lands have been used for agricultural purposes are in California, where the islands or deltas of the San Joaquin and the Sacramento have been diked off, drained, and made into

Figure 43.—Sawgrass marsh. (Marsh grass.) Hummocks in background. The great coast marshes are inundated at high tide by salt water, but have not become excessively saline. In many places, such as the Everglades, the water-supply is practically entirely fresh. There is great variation in the botanical composition of the marshes, but the type shown in the picture is very extensive. Near Detroit, Fla.

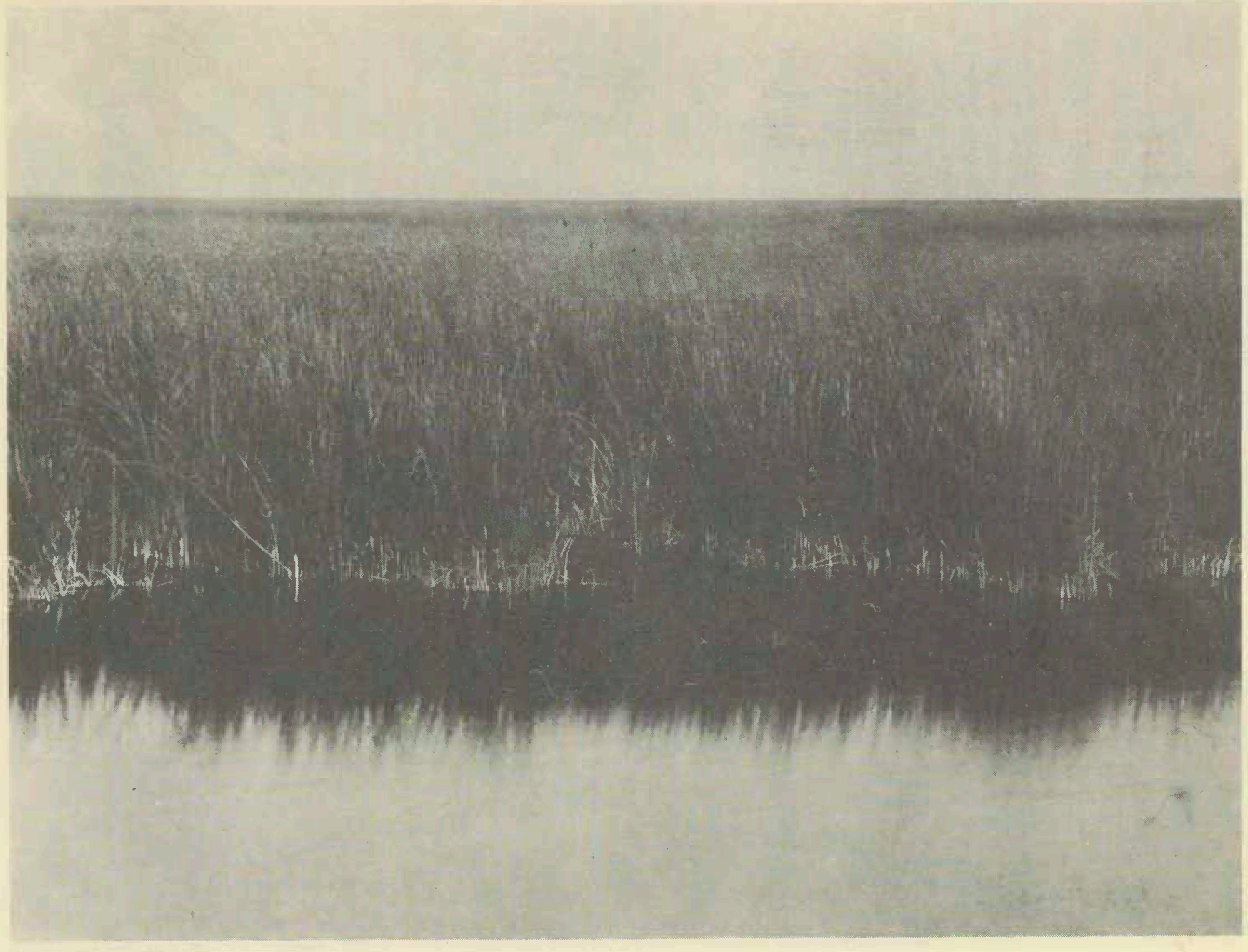


Figure 44.—Pure tule marsh. (Marsh grass.) This is the most prominent type in the western marshes. Often the water is relatively rich in soluble salt. This type is extensive in the Klamath Lake region of Oregon and characterizes large areas in both the San Joaquin and Sacramento Valleys. Klamath Lake, Oreg.

very fertile farm areas, especially for the production of asparagus, onions, potatoes, and barley hay. In southern Louisiana, where land of this type is being drained and used for rice production, and in the Everglades, where an attempt is being made to develop muck land into hay and truck farms, the land has been greatly modified by drainage.

ALPINE MEADOW (ALPINE GRASSLAND).

The alpine type occupies much of the mountain land above the timber line (figs. 2 and 3), and is dominated by rock sedge (*Carex rupestris*), alpine nigger wool (*Carex elynoides*), alpine fescue (*Festuca brachyphylla*), and a great variety of alpine plants, most of which are attractive to botanists as well as to tourists. During early summer it often presents a mass of bright colors, due to the blooming gentians, primroses, saxifrages, foreget-me-nots, painted-cups, buckwheats, lupines, polygonums, erigerons, etc. (fig. 45). The flora is especially rich, and many species essentially Arctic occur. The total area in the United States is relatively small, although Colorado, the northern Rockies, and the Cascade-Sierras have rather large areas of this type. The area shown on the map includes also the great rock-fields, which have only cliff plants and lichens, and the snow fields and glaciers, which are devoid of vegetation.

DESERT SHRUB VEGETATION.

The desert shrub, with all its variations of plant cover, may be reduced to three general types:

Sage brush, or northern desert shrub.
Creosote bush, or southern desert shrub.
Greasewood, or salt desert shrub.

The Great Basin region in Utah, Nevada, and Oregon and similar areas in northern New Mexico, Arizona, and California may be characterized as sagebrush desert (fig. 2). The characteristic plants are small deciduous shrubs, deep-rooted for the most part, capable of enduring long periods of rest due either to drought or cold, and with growth limited by available water and favorable temperature. Cacti are characteristically absent from this desert. The rainfall is rather evenly distributed througout the year and for the most part is low, varying from 5 to 15 inches. The character of the vegetation indicates usually the amount of water available for growth. Throughout the area drought may occur at almost any time, and the plants, although well adapted for extreme drought, are often killed by prolonged dry periods. The appearance of the vegetation is monotonous, and the traveler is impressed by the great expanse of pure stands of a single species.

The southern portion of the Great Desert may be characterized as the creosote-bush desert (fig. 2). The evergreen creosote bush is as prominent in the southern desert as the sagebrush in the northern desert. Mesquite ranges throughout this southern area, although it is relatively more important in the eastern part. Yucca, cacti, and spiny desert shrubs are often prominent. The water supply varies greatly, and prolonged droughts may occur at any time. In the drier portion the average rainfall may be as low as 2 inches per year, with droughts lasting from 2 to 6 months, or in extreme cases for a year or more. In other sections the rainfall may be as much as 20 inches and have a fairly even distribution. In this region there are two rainy periods, one in winter and one in summer (with a tendency toward a spring and fall maximum in the southeastern portion), and growth is limited by moisture supply and little or not at all by low temperatures.

The appearance of this desert is markedly different from that of the northern desert. On the whole the plants are larger, more luxuriant, and more widely spaced. Many of them are succulent or evergreen and hold their leaves during the long periods of drought. In the southern portion, especially in the regions of comparatively high rainfall, such as southeastern Arizona, New Mexico, and Texas, this type is mixed with the desert grassland area. On the west this desert merges gradually into chaparral.

At lower elevations than the sagebrush and the creosote-bush deserts is the greasewood desert, bordering the drainage channels and occupying undrained basins, especially those underlain by artesian water (fig. 2). This type differs from other desert types in being limited largely to wet or subirrigated land containing a high percentage of soluble salts. Its most characteristic plant is the greasewood, which presents to the eye during periods of active growth a deep-green luxuriant appearance. Most of this desert is characterized by green, fleshy-leaved plants, and to one unaccustomed to alkali deserts it seems much less desert like than the drier areas of sagebrush or creosote bush of higher elevations. Over most of its area this desert is limited to tracts only a few miles across, and only the larger districts can be indicated on the map.

Figure 45.—Alpine grassland made up of grasses and sedges, with many low-growing, showy flowering plants. (Alpine meadow.) Timber line shown below. The flowers in the foreground are Polygonum bistortoides and painted brush (Castilleja occidentalis). Above Lawn Lake, Colo. Photographed by Wiswall Brothers.

SAGEBRUSH (NORTHERN DESERT SHRUB).

This group is characterized by a scattered open stand of deciduous shrubs, almost all of which have small leaves of a light or silvery color. (Figs. 46 to 50.) The plants are woody and seldom exceed 50 years in age. The plant cover usually consists of a single perennial species, the individual plants of which are unusually uniform in size and general habit. These great expanses of silver or ash colored vegetation present a monotonous appearance.

Of the three types of desert vegetation, sagebrush is the most extensive. Although at high altitudes sagebrush extends to the Mexican boundary, it occurs only as small isolated patches south of latitude 34°. From latitude 37° north to the Canadian line most of the lower valley or basin land between the Cascade-Sierra on the west and Continental Divide on the east is occupied by this type of vegetation. It also occurs in the upper part of the Rio Grande basin and in the Bighorn, Laramie, and Casper basins in Wyoming. In a somewhat modified form it pushes far into the grassland areas of the Great Plains, especially in Montana and Wyoming, where it occurs as a dwarfed sagebrush alternating with grassland, especially in the Yellowstone, Missouri, North Platte, and Bighorn drainage basins. It also occurs in Colorado along the eastern base of the mountains, especially in the valley of the Arkansas.

This northern desert shrub type pushes into the short grass type of vegetation chiefly as sagebrush; into the bunch grass (wheat-grass bunch) as sagebrush, bitterbrush, or scabland sage; into the piñon-juniper as sagebrush or small sage; and into the southern desert as shadscale. As a rule the line of demarcation is not sharp between the sagebrush and piñon-juniper, but sharp alternations occur, the sagebrush usually occupying the better type of soil and the piñon-juniper the more rocky soils. The desert shrub extends into the drier valleys east of the Rocky Mountains in the north, while the short grass pushes into the desert areas west of the mountains, especially in the south.

This great area of sagebrush desert is characterized by rainfall which is comparatively uniform throughout the year, being least during the months from July to September. Over much of the area the rainfall is less than 10 inches and in very little, if any, of the area does it exceed 15 inches. The rainfall comes largely during the long winter rest period and finds its way deep into the soil. Many of the characteristic plants are deep-rooted. The evaporation rate is relatively high and the total amount of annual growth small. The frost-free period varies from 90 to 150 days, but the growing period is usually much shorter on account of drought. This great unit of vegetation is by no means uniform and may be subdivided into several types dominated by a practically pure stand of a single perennial species.

Agriculture in the northern desert is limited to local areas. The best of the sagebrush land has been utilized for grain production under dry-farm methods, while a considerable area in many of the larger valleys of Idaho, Utah, and Nevada has been put under irrigation. Both winter and spring wheat, oats, barley, and rye are grown. Alfalfa is one of the most important crops of

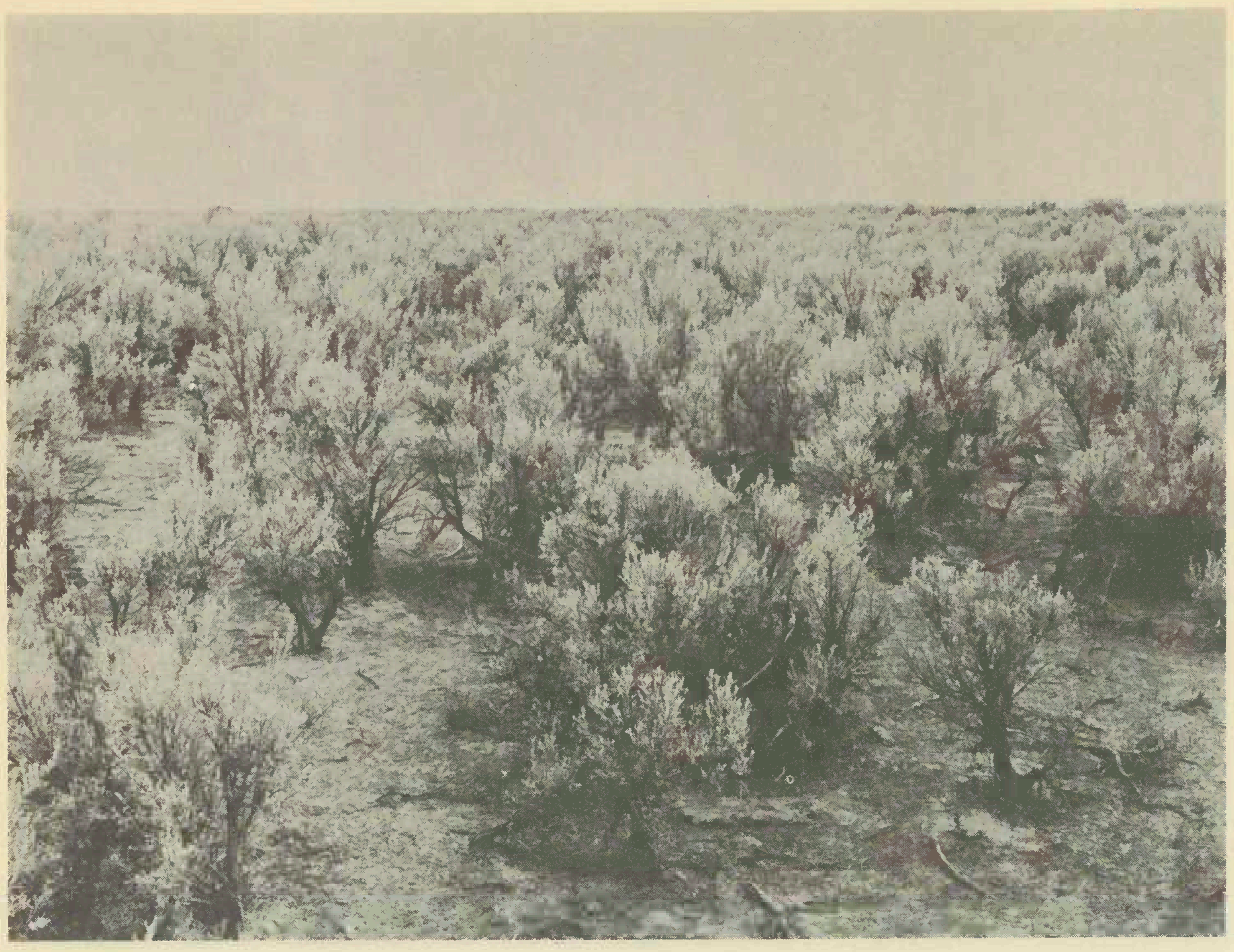


Figure 46.—A pure stand of sagebrush about 4 feet high and resembling an open miniature forest. (Sagebrush.) Annuals form the bulk of the associated species. Sagebrush is the most important plant of the northern desert shrub vegetation. It draws its moisture-supply from both the surface and deep soil layers. Growth is confined to spring and early summer, the plants passing the later summer and fall in a leafless drought-rest condition. During extreme drought sagebrush is often killed. The plants here illustrated range from 30 to 50 years in age. A thrifty growth of sagebrush indicates the best type of land found in the Great Basin region—a deep soil free from harmful amounts of salt. Land of this type may produce fair crops of wheat under dry farming. Nephi, Utah.

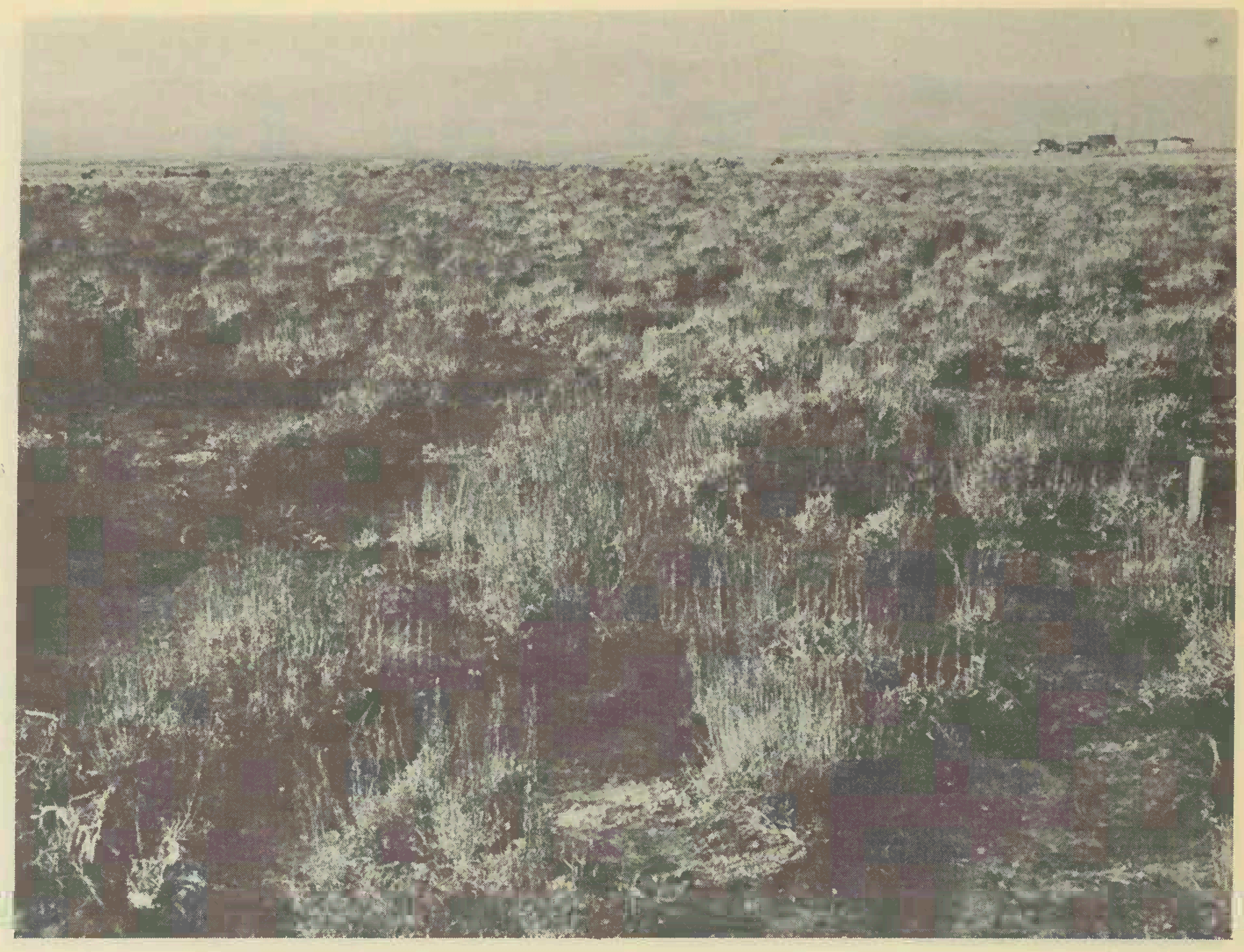


Figure 47.—Small sage about 18 inches high. (Sagebrush.) The conditions in this type are more adverse than in sagebrush. The soil is usually shallow and stony, unfavorable for cultivation. Small sage is difficult to distinguish from poorly developed sagebrush. In general the plants are smaller, less silvery and more yellowish in color. Small sage land is seldom used for crops, and its value for grazing depends upon the amount of grass growing between the small sage plants. Ely, Nev.

the region, and sugar beets and potatoes are also extensively grown. Much of the best irrigated fruit land of the intermountain region, which is especially productive of apples, peaches, and similar fruits, is found on land previously growing sagebrush, shadscale, or salt-sage. The development of irrigated land has been determined up to the present time more largely by the practical problems attending the application of water than by the physical condition of the soil or the presence or absence of alkali. As grazing land the winter-fat and the bud-sage areas are important sources of forage. All of the area is grazed, especially in winter, but much of the forage value lies in the relatively unimportant or secondary species of grasses and other forage plants. Overgrazing, and the resulting reduction of fire risk and the conservation of soil moisture in the subsoil, has greatly extended the sagebrush desert into the grassland area.

The sagebrush desert shrub is divided into three main associations, under each of which may be grouped a number of the more important minor communities:

- Sagebrush (*Artemisia tridentata*):
  - Small sage (*Artemisia nova*).
  - Scabland sage (*Artemisia rigida*).
  - Little rabbit brush (*Chrysothamnus stenophyllus*).
  - Bitterbrush (*Purshia tridentata*).
  - Big rabbit brush (*Chrysothamnus nauseosus*).
  - Coleogyne (*Coleogyne ramosissima*).
  - Chamiso (*Atriplex canescens*).
  - Match weed (*Gutierrezia sarothrae*).
- Shadscale (*Atriplex confertifolia*):
  - Winter fat (*Eurotia lanata*).
  - Hop sage (*Grayia spinosa*).
  - Bud sage (*Artemisia spinescens*).
- Salt sage (*Atriplex corrugata* and *A. nuttallii*):
  - White sage (*Kochia americana vestita*).

Sagebrush (fig. 46).—The most important plant of the northern desert shrub is sagebrush (*Artemisia tridentata*). It occupies most of the higher land which is free from alkali, well drained, easily penetrated, and moistened by natural rainfall or by flood waters to a depth of from 4 to 18 feet. This type is best developed in the northern and more elevated portion of the area and within the region where the rainfall is from 10 to 15 inches. It is characteristic of the great alluvial fans and plateaus, ranging principally from 4,000 to 7,000 feet elevation in the central and southern portion of the area and from 1,000 to 2,000 feet in the Columbia Basin. It occupies much of the desert lands of Washington, Oregon, Idaho, Wyoming, Montana, Colorado, Utah, Nevada, northern New Mexico, Arizona, and northeastern California. It ranges from the Canadian boundary on the north to the Mexican boundary on the south, where it occurs in relatively restricted areas at high elevations, and in California usually well up above the chaparral and next to the yellow-pine belt.

The sagebrush cover is usually a pure open stand, the plants being from 3 to several feet apart and varying in height from 2 to 7 feet. In general appearance this type represents a diminutive forest with silvery foliage and little undergrowth. Growth is confined largely to spring and early summer. In late summer and fall sagebrush passes into a drought-rest condition, during which it drops its leaves gradually. At such times the bare stems appear dark in color, and the name "black sage" is often applied to it. During periods of extreme drought sagebrush is often killed over large areas. During rainy periods annuals spring up and grow until the moisture supply of the surface soil is exhausted. These consist largely of the introduced annual brome (*Bromus tectorum*), filaree (*Erodium cicutarium*), and similar desert species. The sagebrush roots are well developed at the surface and extend also in good soil to a depth of 4 to 18 feet. A good, even stand of large sagebrush indicates land upon which crops can be successfully grown by dry-farm methods. Much of the land under irrigation, especially by the small private irrigation systems in which the water is taken directly from the mountain streams and utilized on the adjacent land, was originally characterized by this type of vegetation. Small, old plants, or a stunted, gnarled appearance of the sagebrush, indicates either harmful amounts of alkali in the second or third foot of soil or a water supply so limited that plants can not develop to their full size.

Small sage (fig. 47).—Within the area usually dominated by sagebrush there occur a large number of

Figure 48.—A pure open stand of little rabbit brush. (Sagebrush.) The plants are bright yellow in color when in flower and are usually about 18 inches high. There are few associated plants. Little rabbit brush is most extensive in Utah, and is characteristic of a loose, alkali-free soil, not differing markedly from sagebrush land. Lindyl, Utah.

minor divisions. In Oregon and Idaho and more elevated portions of Utah and Nevada, Wyoming, and Colorado, where soil-moisture conditions are less favorable, due to greater run-off caused by a less disintegrated soil, shallow stony land, or a heavy adobe, sagebrush gives way to small sage (*Artemisia nova*).

This change is seldom due to less rainfall. In general appearance the type is quite distinct from well-developed sagebrush. Very poor sagebrush is distinguished from it only with difficulty. The plants, not as tall as sagebrush, are less silvery and more yellowish in color, and do not have the appearance of a miniature forest. The stand is usually pure, scarcely any other prominent perennials occurring in this type. As agricultural land this type is of doubtful value, due to the rocky and shallow soil, and its value as grazing land depends entirely upon the small amount of grass and other herbage which develops in the interspaces.

Scabland sage.—In Washington and Oregon the lava outcrops known as scabland are occupied by scabland sage (*Artemisia rigida*), a low-growing gnarled bush seldom exceeding 2 feet in height. During the wet spring period many flowering herbs appear in this type. The climatic conditions are similar to those of the wheat-grass or sagebrush areas of the region. Land occupied by this type is entirely unsuited for agriculture and inferior to the adjacent areas of wheat grass or sagebrush as grazing land.

Little rabbit brush (fig. 48).—In the southern portion of the area, in Utah and Nevada, little rabbit brush (*Chrysothamnus stenophyllus* and related species) occupies large areas to the exclusion of almost all other plants. During the summer when the flowers are in bloom, such areas present a uniform bright-yellow expanse often extending for many miles. The plants are, as a rule, not over 12 to 18 inches in height. On soils poorly supplied with water they are often only a few inches high. The amount of growth indicates roughly the quantity of soil moisture available each season for plant growth. The type occurs on rather light land which is free from alkali, and indicates conditions a little less favorable for dry farming than sagebrush. In places where drought or fire has killed out the sagebrush this type of vegetation often develops. Only during favorable years will sagebrush replace this type.

Bitterbrush.—On sandy or loose volcanic soils or poorly disintegrated rocky soils in the northern and western portions of this desert, bitterbrush (*Purshia tridentata*) characterizes large areas. It is found for the most part at higher elevations and near the yellow-pine zone. The large, dark-green plants present an appearance quite different from sagebrush. The conditions do not differ essentially from those on sagebrush land, except that the soil is more loose and sandy.

Big rabbit brush.—Where sagebrush has been destroyed, or on sandy land in the northern portion of the desert, big rabbit brush (*Chrysothamnus nauseosus*) is often dominant. It indicates conditions not essentially different from those of sagebrush. The plants are very light in color, with relatively inconspicuous leaves, grow rapidly, and are short-lived. Late in the season they are covered with yellow flowers which hide the stems and foliage almost entirely.

Coleogyne.—At the southern edge of the sagebrush desert coleogyne (*Coleogyne ramosissima*) often becomes one of the most prominent features of the desert shrub. On the highlands west and east of Death Valley, also across Nevada at the thirty-seventh parallel, it forms the boundary between the northern and southern desert, mingling with northern types on the upper or northern boundary and with the tree yuccas on the lower or southern boundary. It does not occur in alkali soil, but on alluvial fans or sandy soil, where the total rainfall is quickly absorbed and available for plant growth. This land is suitable only for irrigation agriculture.

Chamiso.—Chamiso (*Atriplex canescens*) occurs in many places either in a pure stand or as scattered plants over a Galleta grass cover. In distribution it occurs in the southern portion of the northern desert shrub, but is more abundant in the southern desert shrub, to which it apparently belongs. Chamiso often occupies sandy land, although it has been found in a pure stand on heavier land containing some alkali.

Match weed.—Large tracts of land throughout the desert are marked by a cover of match weed (*Gutierrezia sarothrae* and related species). Such lands have been either burned, plowed, overgrazed, or disturbed in some way, and match weed represents only an early perennial stage in the revegetation. These vast areas may have been originally sagebrush land, shadscale land, or any other permanent type. As an indicator it is of little practical value, although the best and most luxuriant growth is usually on sagebrush land and the poorer growth on shadscale or salt-sage land. This type also occurs on short-grass lands and lands of the southern desert when the original vegetation is disturbed or destroyed. Its natural habitat seems to be the shallow soils of the western and southern edge of the short-grass area.

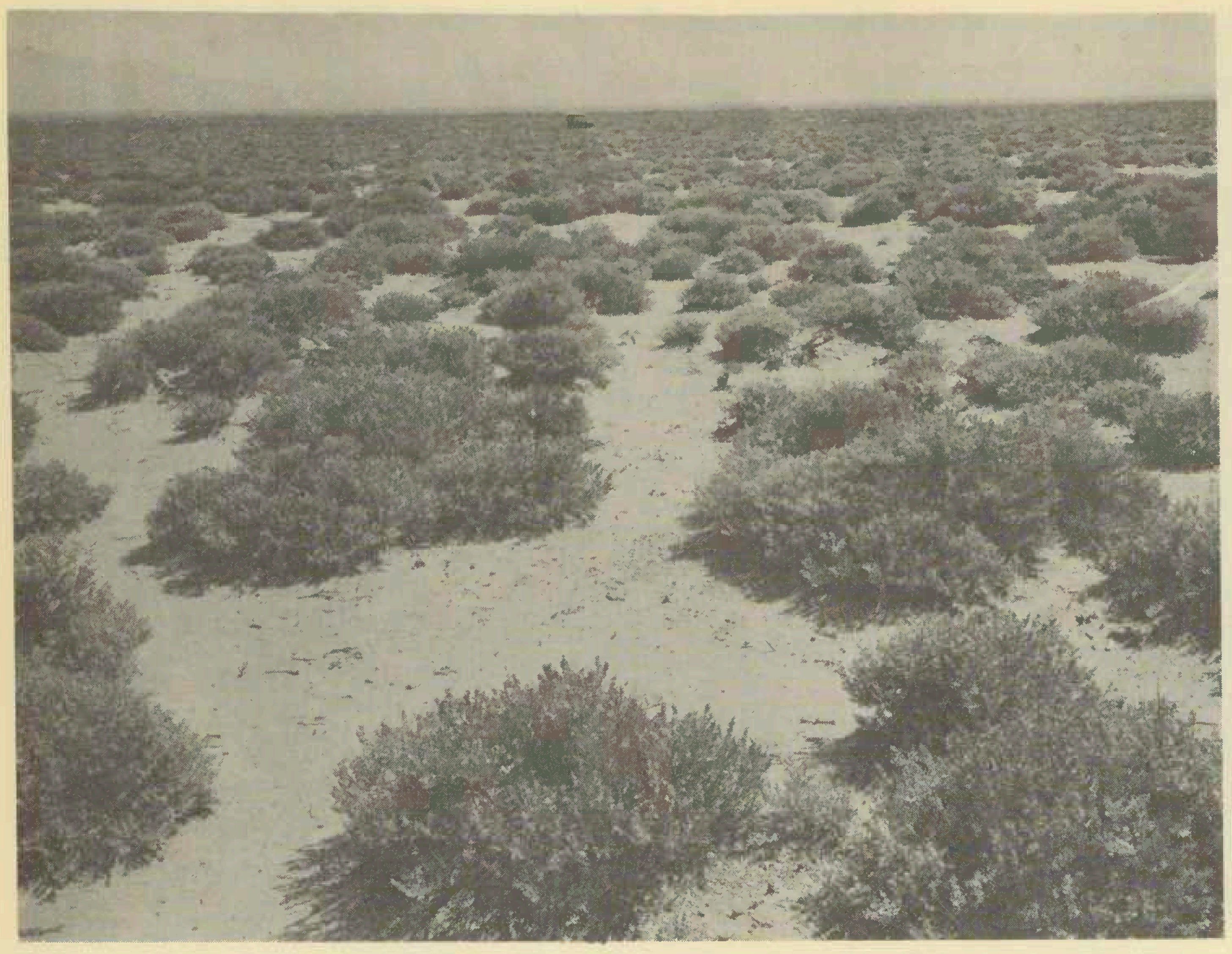


Figure 49.—A pure open stand of shadscale plants about 1 foot high. (Sagebrush.) One of the most extensive types of the northern desert shrub. The few associated plants contribute little to the general appearance. In growing condition or in dormant condition the plants are ash-gray in color, blending with the desert soil. The branches are rigid and the individual plants tend to form low hummocks. This is the most important type of the southern part of the Great Basin, where the temperature is higher and the rainfall lower than on sagebrush land. The soil indicated by shadscale is usually shallow or heavy and strongly saline in the deeper layers, and is, consequently, not suitable for dry-farming. Lund, Utah.

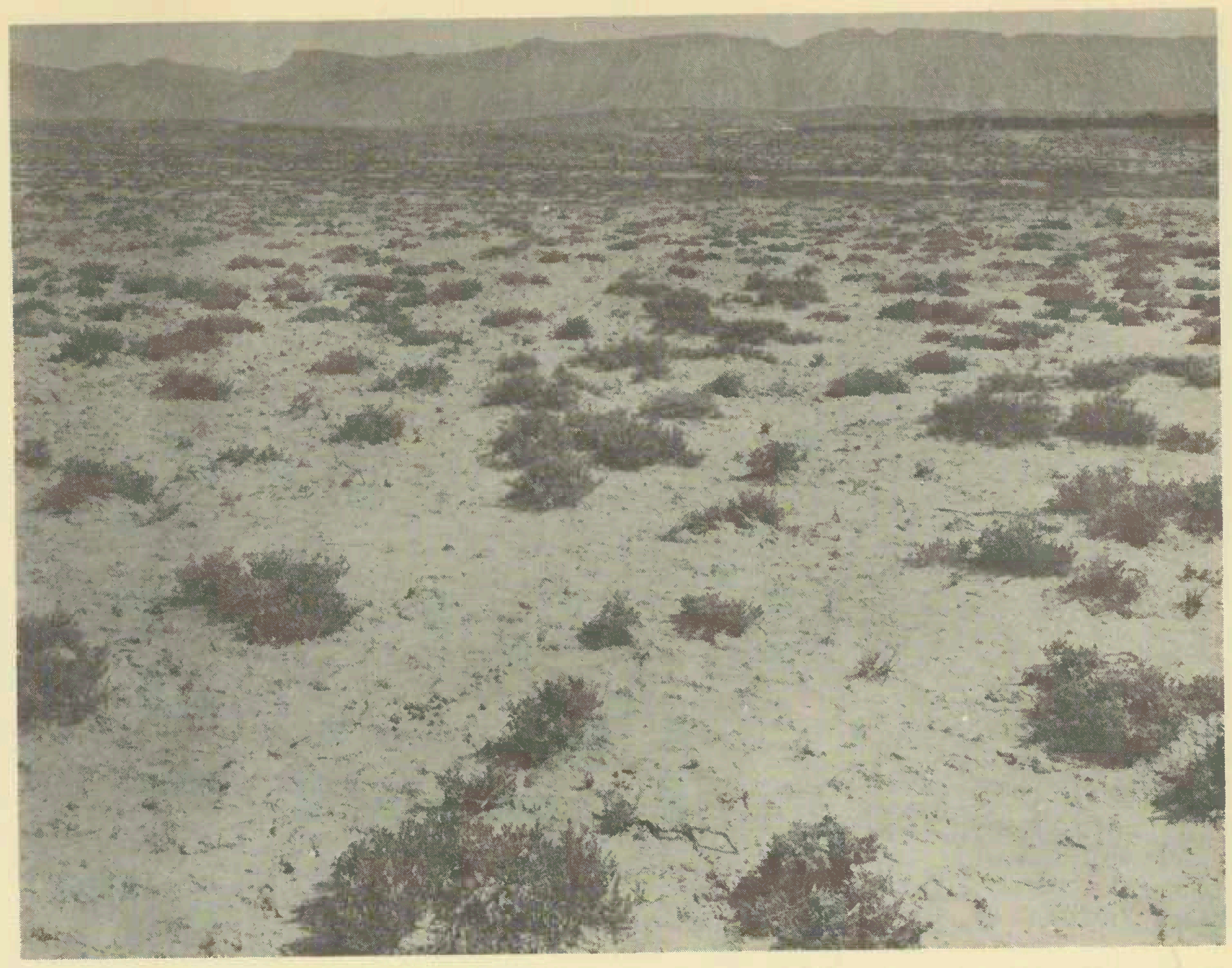


Figure 50.—Mats of salt sage with plants about 5 inches high. (Sagebrush.) The small, widely spaced mats blend with the desert soil and give a barren appearance. Next to the barren salt flats, this is the scantiest desert vegetation. Salt sage occurs on land from which the run-off is large, the moisture conditions being even more severe than on shadscale land. The rains penetrate usually only a few inches, and alkali is often found to the very surface. Near Grand Junction, Colo.

Shadscale (fig. 49).—The shadscale (*Atriplex confertifolia*) covers an extensive area in Utah and Nevada, and occurs less abundantly in Wyoming, Colorado, southern Idaho, Oregon, and eastern California. In relatively small isolated areas it pushes south into New Mexico, Arizona, and into the Mohave Desert of California. It usually lies below the sagebrush and just above the salt-desert shrub. Where ground water lies at a depth of several feet, greasewood often occurs as scattered widely spaced plants on land otherwise characterized by shadscale. This is one of the most common mixed types of the northern desert region. Shadscale also comes in contact with the short grass east of the mountains in Colorado and in New Mexico and Arizona. It probably covers more land in Nevada and Utah than does the sagebrush. The rainfall is less than over sage land and the heavy character of the soil much more conducive to high run-off. As compared with sagebrush land the moisture conditions are much more extreme. The root system is much shallower than that of the sagebrush, due to the more limited water supply. During periods of extreme drought this plant is often killed over large areas. Like the sagebrush, it is characterized by a practically pure stand.

In contrast with the silvery foliage of the sagebrush, the shadscale is gray, and the whole landscape presents an appearance of extreme monotony. In autumn the plants change to a reddish-brown color, and during the favorable years a heavy crop of seed is produced. The plants are hemispherical and usually scattered evenly over the surface of the soil, but never produce a dense stand. Between the plants the soil usually is bare. The plants vary in height from 6 inches to 2 feet. If the soil is especially poor and the rainfall unusually light, the plants may be only a few inches high. On relatively good soil the plants may be 2 feet high. This type indicates harmful amounts of alkali at a depth of 1 or 2 feet or a soil poorly supplied with water with a hardpan at the same depth. This land is unsuitable for dry farming, but where the soil is not too shallow it can be made productive under a proper system of irrigation.

Winter fat.—Within the zone occupied by the shadscale, occurring on similar soil and under similar climatic conditions, are a number of minor groups. Winter fat (*Eurotia lanata*) covers hundreds of square miles in Nevada and Utah. The plants are usually small, almost white in color, and rather widely spaced. Areas can be detected at great distances because of the uniform white or light-gray color, which at a distance appears like snow. The plants are shallow rooted and often grazed almost to the ground. This plant occupies land almost as heavy as that covered by shadscale, but which contains only a small amount of alkali. It is one of the most valuable forage plants of the Great Basin region, and is especially highly prized by sheepmen. Although the pure areas are most extensive in Nevada and Utah, it is a common plant over a much wider range and contributes much to the forage resources of the intermountain region. Agriculturally this is similar to the shadscale land.

Hop sage.—Under conditions intermediate between shadscale and sagebrush large areas occur which are occupied by hop sage (*Grayia spinosa*). During the winter this shrub presents very much the appearance of sagebrush, with which it is often mixed. It is found most commonly in the northern portion of the area.

Bud sage.—Bud sage (*Artemisia spinescens*) is especially prominent in Nevada and occurs throughout Utah, Colorado, and the Northwest. It occupies rather limited areas and does not differ markedly from the shadscale in its distribution. It is especially valued by sheepmen. Sheep which, during the winter, have grazed on winter fat are first moved to areas of bud sage because the young shoots of this plant produce excellent forage and constitute the principal feed in the early spring.

Salt sage (fig. 50).—Salt sage (*Atriplex corrugata*, *A. nuttallii*, and allied species) ranges somewhat farther north than shadscale and occupies especially large areas in Wyoming, Colorado, and Utah. It occurs in small areas in Montana, Idaho, Oregon, and California. In Montana, Wyoming, and Colorado it pushes out into the short-grass areas, but never becomes dominant over large areas east of the mountains. Great expanses are covered with this ash-colored low-growing plant, which forms large mats and is seldom more than a few inches high. The total amount of growth produced on this type is small, and the landscape presents to the eye a relatively larger amount of bare ground from which the plant is not readily distinguished at a distance. It occurs usually on a soil from which the run-off is comparatively great and which accordingly supplies only a small amount of water for plant growth. The moisture conditions are even more extreme than on shadscale land. Soil moisture is confined to within a few inches of the surface, and only a relatively small total moisture supply is available for plant growth. Plant growth occurs largely in early spring, and the plants pass most of the summer season in a rest condition. This type is found usually in regions having less than 10 inches of rainfall and a high evaporation rate. The soil usually contains harmful amounts of alkali to the very surface. Land under this type of vegetation is not adapted to dry farming, but when the proper system of irrigation is applied it may be leached so as to become good agricultural or orchard land.

White sage.—Land similar to that occupied by salt sage is sometimes dominated by white sage (*Kochia americana vestita*). These areas are found in portions of Utah and Nevada, and are not extensive. In appearance they can be distinguished with difficulty from winter-fat areas. The two species are of about equal height as a rule, but the white sage is not as white as is the winter fat. White sage spreads by underground rootstocks, the plants are evenly distributed, the spaces between the plants being either bare or occupied usually by a small grass (*Poa sandbergii*). As a rule the surface of the soil is very light in color and a decidedly heavy loam in character. Alkali, while not noticeable at the surface, is abundant at a depth of 10 inches or 1 foot, and during most of the year the soil at a depth of 1 foot is moist, owing to the high alkali content, which inhibits the production of plant roots in this zone. Because of its compact character and high alkali content, land characterized by this plant is unsuited for irrigation agriculture, unless the alkali can be leached to some extent. During years of unusually well distributed rainfall land of this type will produce crops under dry-land culture, but it should not be regarded as productive dry-farm land. White sage is only grazed to a small extent, and the grazing value of this land is due to the associated grasses.

CREOSOTE BUSH (SOUTHERN DESERT SHRUB).

This type presents a much more varied appearance than the sagebrush desert. (Figs. 51 to 56.) The most important plants, creosote bush and mesquite, are shrubby, or sometimes the latter is treelike and continues growing through long periods of drought, having a much longer growing period than sagebrush. Yuccas, cacti, and spiny desert shrubs are prominent in many parts of this desert.

This desert occupies a comparatively narrow belt across the southern portion of the United States from the Pacific Ocean to the Gulf of Mexico. It does not occur to any extent north of the thirty-seventh parallel. Along the Virgin River in southern Utah this type reaches its most northerly limit. It is confined almost entirely to the Mohave Desert, the valleys of the Colorado, the Gila, the Rio Grande, and the Pecos. A small area of inland valley land in southern California, west of the main range, has also been included. The climatic conditions in this desert are more extreme than in any other portion of the country. The rainfall varies from about 2 to 20 inches, and the greater portion of the area receives less than 15 inches of rain. Over most of the area west of the Colorado River no rain falls during the hot summer months, the great portion occurring during the winter months. In other sections, on the contrary, especially those lying in Texas and New Mexico and the southeastern portion of Arizona, the rainfall during the summer is greater than that during the winter. Here grasses become relatively abundant. The temperature over all this area is high, often reaching 100° to 125° F. Over much of the area it rarely falls below 20° to 25° F., and the frost-free period usually ranges from 180 to 270 days. Because of the intense heat and the very rapid evaporation the conditions in portions of this area are more extreme for plant growth than in the northern desert shrub, although in many parts the wide spacing of the plants and the pervious nature of the soil combine to supply a quantity of available moisture sufficient to enable the desert shrubs to continue growing through extremely long periods of drought, in some cases lasting a year or more.

This desert is not sharply separated from the chaparral zone, into which it merges. On both the coast and the desert side of the mountains of California the great Adenostoma area of the chaparral zone lies just above areas of wild buckwheat or Encelia and California sagebrush, and these types, here classified with the southern desert, could with reason be placed with the chaparral. In the Mohave basin and in other portions of the southern desert the yucca-cactus type merges into the juniper. Shadscale pushes down into this desert from the north, and chamiso is common to both deserts, but is best developed in the southern desert. The line of demarcation between the southern desert shrub and the desert grassland is even more difficult to draw. Over great stretches of grassland are scattered shrubs or other large southern desert plants. On the map, areas dominated by shrubs have been placed in the southern desert, while areas which show only scattered shrubs over the grass cover have been mapped as desert grassland.

This shrub desert lies for the most part in a relatively frost-free area, and wherever water is available

Figure 51.—A dense, even stand of desert saltbush with plants about 4 feet high. (Creosote bush.) The uniform gray stretches of this plant resemble somewhat the sagebrush areas, and the plant is often called desert sage. Where the soil is poor or the moisture-supply deficient the plants are widely spaced. The type is limited largely to the bottom of valleys, but does not grow on soil which is subirrigated. A dense stand is characteristic of good agricultural land, of a soil of fine texture and containing a relatively slight amount of soluble salt. Indio, Calif.

Figure 52.—Creosote bush with a sparse growth of annuals. (Creosote bush.) The widely spaced plants are about 5 feet high. The thin, dark-green, lacquered foliage contrasts sharply with the light-gray color of the desert plantain, which forms an even cover following the winter rains. During the flowering period the bushes are covered with yellow flowers, which are soon replaced by conspicuous hairy fruits. Creosote bush usually draws its moisture supply from the deeper soil layers, and is therefore not dependent on an even distribution of rainfall. It is confined to soil relatively free from alkali. Near Indian Wells, Calif.

a highly specialized type of agriculture is developed. Production ranges widely from alfalfa and small-grain crops, produced as hay, to truck crops, citrus fruits, cotton, and dates. Cotton production in the West is confined largely to this desert, since both the long season and the warm climate are favorable. In the lower parts of the valleys, especially in Arizona and California, are grown the only dates produced in the United States, largely on land of the desert saltbush type.

Although most interesting from a botanical point of view, the southern desert shrub has not been studied in a sufficiently comprehensive way to enable one to present clearly the different types composing it. Over much of the area these types are recognized with difficulty, since there is often a great mixture of species. Viewed as a whole, the area is most often characterized by pure stands. Although it presents great diversity, it may be reduced to the following five main associations, with each of which a number of minor associations or associes may be correlated:

- Desert saltbush (*Atriplex polycarpa*).
  - Narrow leaf saltbush (*Atriplex linearis*).
  - Desert saltbush–mesquite (*Atriplex polycarpa–Prosopis juliflora*).
  - Chamiso (*Atriplex canescens*).
- Creosote bush (*Covillea tridentata*).
  - Creosote bush–bur sage (*Covillea tridentata–Franseria dumosa*).
  - Black brush (*Flourensia cernua*).
- Yucca-cactus.
  - Yucca–cholla (*Yucca mohavensis–Opuntia bigelovii*).
  - Joshua tree–wild buckwheat (*Clistoyucca brevifolia–Eriogonum fasciculatum*).
  - Cactus–palo verde (*Carnegiea gigantea–Cercidium torreyanum*).
  - Lechuguilla–sotol (*Agave lechuguilla–Dasylirion texanum*).
- California sagebrush.
  - California sagebrush–encelia (*Artemisia californica–Encelia farinosa*).
  - Wild buckwheat (*Eriogonum fasciculatum*).
- Mesquite (*Prosopis juliflora*).
  - Cat's claw (*Acacia gregii*).
  - Mesquite–chamiso (*Prosopis juliflora–Atriplex canescens*).
  - Mesquite–rayless goldenrod (*Prosopis juliflora–Isocoma coronopifolia*).

Desert saltbush (fig. 51).—The desert saltbush type covers extensive areas in California, Nevada, and Arizona, where often it is referred to as desert sage. The uniform gray stretches of this plant (*Atriplex polycarpa*) somewhat resemble the sagebrush areas of the northern desert shrub. For the most part the plants occur in dense thickets from 3 to 4 feet high on fine loam soils well supplied with moisture, which is largely derived from drainage. On the poorer land, and on land from which there is a run-off or which receives only the normal rainfall, the moisture supply is insufficient to produce a dense stand, and scattered plants 2 or 3 feet high and widely spaced are characteristic. This type is limited largely to the valleys, where it occurs just above the salt desert shrub, on fine loam soils impregnated with a moderate amount of salt or alkali. The desert saltbush does not occupy land which is subirrigated. The agricultural value of land characterized by desert saltbush is probably greater than that occupied by any other type in the southern desert region, and much of the land now under irrigation was formerly thus characterized. A good growth of desert saltbush indicates a good deep soil of fine texture with a considerable amount of alkali. Under a system of careful irrigation this land is very productive.

Narrow-leaf saltbush.—Where conditions are relatively less favorable for plant growth, due to more compact subsoil with high salt content, the narrow-leaf saltbush (*Atriplex linearis*) is found. It occurs in southern Arizona below the desert saltbush and above the seepweed of the salt desert shrub.

Desert saltbush–mesquite (fig. 53).—If ground water or subsoil conditions are favorable for the growth of mesquite, scattered trees occur in the even cover of desert saltbush. This type is usually confined to the lower part of the desert-saltbush land in Arizona, Nevada, and California, and indicates conditions favorable for crop production under irrigation. Here the mesquite trees are often large, ranging from 15 to 30 feet in height. Sand ridges in the desert-saltbush area are often covered with chamiso (*Atriplex canescens*).

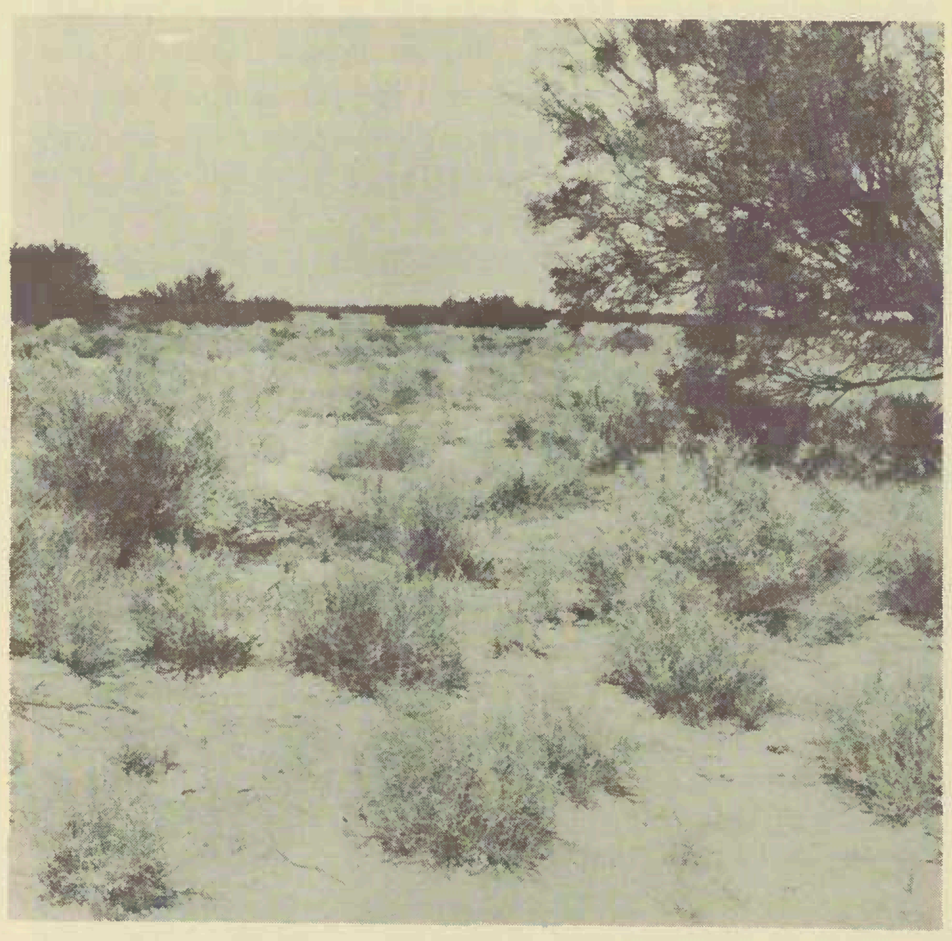


Figure 53.—An open stand of desert saltbush with scattered mesquite trees. (Creosote bush.) The wide spacing of the desert saltbush indicates a relatively deficient soil moisture supply, but the presence of the mesquite trees indicates water available in the subsoil due probably to a water table within reach of the roots. Las Vegas, Nev.

Creosote bush (fig. 52).—This type of vegetation is more extensive in the southern desert than any other type, and occupies the region lying between the desert saltbush and the yucca-cactus zone above. It is abundant in southeastern California, southern Nevada, western and southern Arizona, southern New Mexico, and extreme western Texas. The plants (*Covillea tridentata*) vary from a foot or two to 10 or 15 feet in height, depending on the unfavorable or favorable moisture supply, and are usually very widely spaced, the intervals varying from a few feet to 100 feet or more. In Arizona and California, following the winter rains, the spaces between the plants are covered with a rather dense growth of annuals, of which desert plantain (*Plantago erecta*) is one of the most frequent (fig. 54). The appearance of the whole is that of a widely spaced orchard of small trees or bushes. The plants consist of branches which radiate from near the ground and form a very open shrub. The shrub appears very dark green, almost black, as compared with the light desert soil and the silvery Plantago. In the western part of its range it usually indicates several feet of very permeable light soil, well drained, with low run-off, and with a relatively abundant supply of available moisture in the surface 3 to 6 feet of soil after the rainy period, which comes in winter in the Colorado Desert and both in winter and summer east of this region. In the early spring in the Colorado Desert the plants are covered with bright yellow flowers. During summer and autumn the plants retain their leaves but present a brownish appearance and remain in a condition of drought dormancy. This type indicates a relatively alkali-free soil. In respect to soil and alkali conditions it is similar to the sagebrush of the north desert shrub, and like the sagebrush reaches its best development on the alluvial fans which are often composed of coarse sand and gravel. In the eastern part of its range, under much heavier rainfall, it often indicates a very shallow soil and caliche.

In portions of Arizona, New Mexico, and Texas creosote bush forms a scattered growth over a relatively pure grassland sod. Such areas constitute a transition from the southern desert shrub to the mesquite grass or desert grassland.

Creosote bush–bur sage.—Above the areas of pure creosote bush in the Colorado Desert there may be distinguished a zone of varying width characterized by a mixture of the dark lacquer-leaved creosote bush and the low, light-gray bur sage (*Franseria dumosa* or *F. deltoides*). This type is not sharply differentiated from the yucca-cactus type.

Black brush.—In portions of Arizona, New Mexico, and Texas black brush (*Flourensia cernua*) constitutes the chief component of the vegetation. It lies either above or below the grassland, and occurs only on the better, deeper soils in the creosote-bush areas.

Yucca–cactus.—Lying above the creosote-bush zone there may be distinguished a broad zone made up largely of yuccas, century plants, cacti, palo verde, and related plants. It is varied in appearance and in botanical composition, and is characterized almost throughout its range by a greater mixture of species than is either the desert saltbush or creosote bush. For the most part it is found on the relatively rapidly eroding hills and ridges, the rough slopes, and low mountains of the southern desert region. Only rarely does it push down over the level stretches of the valleys, but reaches its lowest extension along the washes. Although the botanical composition varies considerably, this zone is set off sharply from all the other desert areas by the abundance of the yucca-like plants and cacti which here become prominent features of the vegetation. Very little of the land occupied by this type of vegetation is suitable for agriculture, and the grazing value of the natural vegetation is slight, although during periods of extreme drought cattle are able to subsist upon the relatively unedible plants which characterize this vegetation unit.

Yucca–cholla.—At higher elevations on the west and north side of the Colorado Desert, Mohave yucca (*Yucca mohavensis*) and cacti (*Ferocactus acanthoides*, *Opuntia bigelovii*, and *Opuntia acanthocarpa*), together with shrubs of bur sage (*Franseria dumosa*) and encelia (*Encelia farinosa*) constitute the major portion of the plant cover.

Figure 54.—Joshua trees and wild buckwheat. (Creosote bush.) The trees are about 25 feet high and present a unique appearance. The soil is loose and sandy and free from injurious amounts of alkali. Dry farming is seldom successful. Under irrigation the land is largely devoted to orchards. Hesperion, Calif.

Figure 55.—Giant cactus, cholla, visnaga, palo verde, ocotillo, and other plants. (Creosote bush.) A luxuriant phase of cactus-yucca vegetation found on rough or rocky land at the upper edge of the desert valleys. This vegetation presents a striking appearance due to the unusual character of the dominant plants. The land is not usually of agricultural value, due to its rough and uneven character. Chandler, Ariz.

Joshua tree–wild buckwheat (fig. 54).—In the Mohave Desert region the Joshua tree (*Clistoyucca brevifolia*) is one of the most picturesque plants. It forms trees of from 15 to 30 feet in height, spaced from 15 to 100 yards apart. Much of the ground is covered by wild buckwheat (*Eriogonum fasiculatum*) and similar low-growing shrubs. Juniper often pushes down into the area from the forest above, and creosote bush up into the area from the desert below. The moisture conditions under this type are relatively favorable, and the soil is light and pervious and free from harmful amounts of salt.

Cactus–palo verde (fig. 55).—The flora and appearance of the vegetation in central and southern Arizona is different from that in the Colorado and Mohave deserts. The vegetation in Arizona is largely palo verde (*Cercidium torreyanum*), cactus (*Carnegiea gigantea, Ferocactus wislizeni, Opuntia fulgida, O. mamillata, O. spinosior, O. echinocarpa*, and *O. acanthocarpa*), and ocotillo (*Fouquieria splendens*), with the smaller and less conspicuous bur sage (*Franseria dumosa* and *F. deltoides*). No portion of the southern desert is more varied or picturesque than this. The great columnar bodies of the giant cactus, the white, spiny, bushlike plants of the palo verde, the tall radiating stems of the ocotillo, and the annual flora following the rainy periods, combine to produce a vegetation of great variety and of unusual interest. The land is rough and the soil is rocky and consequently of little agricultural value.

Lechuguilla–sotol (fig. 56).—In New Mexico and the Big Bend country of western Texas the yuccalike plants and scattered shrubs constitute the dominant vegetation. Lechuguilla (*Agave lechuguilla*) is the most characteristic plant, but sotol (*Dasylirion texanum*) and other species and ocotillo (*Fouquieria splendens*) are also important. The soil is rocky for the most part and of little or no agricultural value. The value of this type for grazing depends largely upon the various grasses from the mesquite grasslands which occur scattered throughout this portion of the desert. During periods of drought the sotol is chopped open and cattle subsist on the thickened bases of the leaves, which are relatively high in sugar content and are considered exceptionally good emergency feed.

California sagebrush.—This type lies below the true chaparral zone and is limited in distribution. It is found in the dry interior valleys or slopes west of the Coast Range of southern California and extends over into the desert below the chaparral on the east side of the range and at higher elevations across southern Arizona. Much of the best irrigated orchard land of southern California was formerly covered with California sagebrush.

California sage–encelia.—On the drier slopes west of the mountains in California encelia (*Encelia farinosa*) forms dense thickets of gray broad-leaved shrubs from 2 to 4 feet high. On the more humid slopes this plant is replaced by California sagebrush (*Artemisia californica*) of about the same size, but with very fine foliage of darker color. During the winter rainy season and in early spring there are many showy flowering herbs. The soil is moistened during this period to a depth of 6 feet or more, and growth continues usually until about midsummer, when this stored moisture is exhausted.

Wild buckwheat.—On especially dry hills below the chaparral on the coast side of the mountains and above the creosote-bush zone on the desert side, pure stands of wild buckheat (*Eriogonum fasiculatum*) cover large areas.

Mesquite.—While mesquite is scattered throughout the southern desert from the Pacific coast to the Gulf of Mexico, it is relatively more important in the eastern portion than in the western. In New Mexico and Arizona the mesquite often constitutes the principal type in the subirrigated valleys. In the extreme western part of the Colorado Desert mesquite thickets occur only rarely and are relatively insignificant.

Cat's claw.—Extensive thickets of cat's claw, practically impenetrable because of the sharp, recurved spines, occur in Texas and portions of New Mexico.

Mesquite–chamiso.—In southern Arizona, New Mexico, and California isolated sandy ridges are usually covered by mesquite (*Prosopis juliflora*) and chamiso (*Atriplex canescens*). In the western part of the desert dunes are often built up around the mesquite trees, which become more and more submerged, only the tips of the branches protruding. On these new areas chamiso is the principal shrub.

Figure 56.—Lechuguilla and sotol. (Creosote bush.) Many desert shrubs, a few cacti, and resurrection plants occur in this type. It is not agricultural land. Sanderson, Tex.

Mesquite–rayless goldenrod.—In portions of Arizona, New Mexico, and California the vegetation consists of scattered low shrubs of rayless goldenrod (*Isocoma coronopifolia*) with small trees of mesquite. This type probably represents land on which the original shrub vegetation has been destroyed and replaced by rayless goldenrod.

GREASEWOOD (SALT DESERT SHRUB).

Within the Great Basin the drainage is often entirely hemmed in by mountain ranges and the salts leached from the soil accumulate in the lower valleys. This is especially true of areas which are characterized by ground or artesian water. The water rises to the surface and by evaporation deposits its load of soluble salts to form salt flats. Even beyond the Great Basin region, in arid sections salts accumulate along the drainage channels and in the bottom lands. Alkali areas are, as a rule, not very extensive, and their extent and distribution can only be indicated on the map. Almost every drainage channel in the arid portions of the United States is lined with a narrow strip of alkali vegetation, and similar vegetation is found on the small salt flats along the coasts. The soils occupied by this type of vegetation are usually moist, but excessively supplied with salts. These salts are usually referred to as alkali, of which there are two types—white alkali and black alkali. The principal salts of white alkali are common salt (sodium chloride), Glauber's salt (sulphate of soda), Epsom salts (sulphate of magnesium), and bittern (magnesium chloride). These salts crystallize on the surface to form a white deposit known as "white alkali." Black alkali is composed of sal soda (carbonate of soda), and known as "black alkali" because of its corrosive action on organic matter. Where it occurs the leachings are dark in color and the deposited salt contains enough organic matter to give it a dark color. Black alkali is much more harmful to vegetation than white alkali.

In appearance this desert shrub varies with the particular type of vegetation represented (figs. 57 to 60). It may present the uniform shrublike growth of pure greasewood, deep green during the growing period, but gray and monotonous during the drought or winter rest period; or a barren white salt surface with only here and there a dark green plant of samphire or pickleweed; or a grass cover with scattered tall plants of rabbit brush; or lawnlike areas of pure salt grass.

The salt desert shrub may be reduced to three main associations, with each of which may be grouped a number of minor associations or associes:

Greasewood (*Sarcobatus vermiculatus*).
- Greasewood–shadscale (*Sarcobatus vermiculatus–Atriplex confertifolia*).
- Seepweed (*Dondia torreyana*).

Pickleweed (*Allenrolfea occidentalis*).
- Samphire (*Salicornia utahensis, S. rubra, S. ambigua*).

Saltgrass (*Distichlis spicata*):
- Tussock grass (*Sporobolus airoides*).
- Rabbit brush (*Chrysothamnus graveolens*).
- Alkali heath (*Frankenia grandiflora campestris*).

Greasewood (fig. 57).—Greasewood plants (*Sarcobatus vermiculatus*) are evenly spaced, from 4 to 7 feet apart, and range from 2 to 5 feet in height. The plants are green in color, due to the succulent leaves, and when in full leaf present a relatively luxuriant appearance, contrasting sharply with the gray of the shadscale or sagebrush. The soil between the plants is often covered with little or no perennial growth. Greasewood is widely distributed, ranging throughout the northern and much of the southern desert. The most extensive areas are usually only a few miles across and lie near the bottom of the valleys or along drainage channels. Land of this type contains harmful amounts of salt and is usually supplied with ground water during a part of the year. It has been successfully irrigated, and much of the best agricultural land of the lower portions of the Great Basin previously bore this type of vegetation.

Greasewood–shadscale.—Between the northern desert shrub and the salt desert shrub in the Great Basin

Figure 57.—Greasewood in a semidormant condition. (Greasewood.) Characteristic of moist, moderately saline soils. It is gray and sagelike in winter and bright green during the growth period. The luxuriant growth is deceptive, since the soluble salt-content of the soil is so high that only with leaching and careful irrigation can the land be made productive. It is characteristic of the bottom of the valleys, where for the most part ground water furnishes part of the moisture supply. The transition from this type to the shadscale is usually very gradual. Lund, Utah.

Figure 58.—A pure stand of seepweed, characteristic of moist, strongly saline soils, where the ground water rises to or near the surface. (Greasewood.) Plants are about 3 feet high, and commonly purple in color, especially late in the season. The amount of salt in the soil is usually greater than in soils growing greasewood, and the land is of doubtful agricultural value. Thermal, Calif.

region, greasewood (*Sarcobatus vermiculatus*) is often scattered through an even stand of shadscale (*Atriplex confertifolia*). The appearance is varied, since the shadscale plants are ashen in color and the greasewood plants bright green. The condition indicated is intermediate between pure shadscale and pure greasewood, namely, a soil containing alkali in the second or third foot but with ground water limited to the deeper soil, not available to the shadscale but available at least during a part of the year to the deep-rooted greasewood.

Figure 59.—A salt flat with scattered hummocks of pickleweed. (Greasewood.) Green plants contrast sharply with salt-covered soil. Soil contains 2 or more per cent of soluble salts. Lower Death Valley, California.

Seepweed (fig. 58).—Throughout the entire range of the salt desert shrub, seepweed (*Dondia torreyana*) occupies land nearer the local water level and a little higher in salt content than that occupied by greasewood. The plants range in height from 1 to 4 feet, are very finely branched, and often purple or dark in color, especially in the latter part of the growing season.

Pickleweed (fig. 59).—On the great salt-flats hummocks of pickleweed (*Allenrolfea occidentalis*) occur, while on soil more favorable for plant growth the plants may have an even distribution and form a relatively close cover. In the southern desert region the plants are often 3 or 4 feet high, but as a rule are much smaller in the northern desert region. They are of dark-green color and very succulent. This type occurs at a lower level than the greasewood and on soil which contains more moisture and is more strongly impregnated with salts. The conditions, therefore, are much more extreme than those indicated either by greasewood or seepweed. Over much of the surface salt incrustations give the soil an almost snowlike appearance. Large areas occur near Salt Lake, and on the alkali flats in Nevada, Arizona, southeastern California, and in the San Joaquin Valley.

Samphire (fig. 60).—Conditions very similar to those indicated by pickleweed are found where the samphire grows. The soil contains as a rule about 2.5 per cent of soluble salt and usually is supplied with ground water at a relatively short distance below the soil surface. The conditions are the most extreme encountered under any type of vegetation in the salt desert shrub. In the region about Great Salt Lake, where it is widely distributed, it is composed of the perennial Utah samphire (*Salicornia utahensis*) and the annual red samphire (*Salicornia rubra*). The annual form is greatly favored by precipitation which leaches slightly the surface soils, and germination is usually best along the drainage channels. The perennial form occurs on scattered hummocks or may form a practically pure even stand. The appearance of the two species is very different, since the annual is a bushlike plant 2 to 6 inches high, which turns very red toward the end of the growing season, while the perennial pushes up almost unbranched stems and does not take on an autumn coloration. Along the coast the salt marshes are similar to the inland areas, but are usually inundated at high tide by ocean water, and are dominated by a different species (*Salicornia ambigua*). These areas are too limited to be shown on the map.

Salt grass.—Alkali flats, especially those over which during flood time a supply of fresh water flows, usually develop a salt-grass cover. Salt grass (*Distichlis spicata*) is a low-growing grass and forms either an open cover with occasional plants from underground runners showing at the surface, or under more favorable conditions a uniform dense sod, in which few other species are prominent. Salt-grass pastures miles in extent occur along many of the watercourses in the Great Basin, the Colorado and Rio Grande deserts, east of the mountains on the Great Plains, in the San Joaquin Valley, and along the coasts. The appearance of this type of vegetation is not markedly different from that of a closely grazed meadow, or of the plains or desert grassland. The principal value of land of this type is for grazing. Only with careful management and some leaching does it produce crops under irrigation. The salt content is generally high (about 1 per cent). The soil moisture is supplied from ground water as well as by flood water and precipitation.

Tussock grass.—Under conditions a little more favorable than those found on salt-grass land, tussock grass (*Sporobolus airoides*) forms either a relatively close sod or a hummocky open cover. This grass is usually closely grazed by rabbits

Figure 60.—Hummocks of Utah samphire on salt flat. (Greasewood.) Characteristic of continuously moist salt flats containing 2 or more per cent of soluble salt. Great Salt Lake, Utah.

and by cattle and horses and contributes materially to the forage production of the region. If not grazed closely this grass is marked by a feathery purple panicle during the flowering period.

Rabbit brush.—In many places rabbit brush (*Chrysothamnus graveolens*) is scattered over a tussock-grass sod, and often becomes so dense that only the brush is evident. The yellow-flowered shrubs stand from 2 to 5 feet high; they grow rapidly and are relatively short-lived.

Alkali heath.—In the San Joaquin Valley alkali heath (*Frankenia grandiflora campestris*), pure or mixed with greasewood or salt grass, is one of the most important salt desert plants.

THE COMMON NAMES OF PLANTS USED IN THIS SECTION OF THE ATLAS AND EQUIVALENT SCIENTIFIC NAMES.

Alkali heath	*Frankenia grandiflora campestris* Gray.
Alligator juniper	*Juniperus pachyphloea* Torr.
Alpine fescue	*Festuca brachyphylla* Schult.
Alpine fir	*Abies lasiocarpa* (Hook.) Nutt.
Alpine larch	*Larix lyallii* Parl.
Alpine nigger wool	*Carex elynoides* Holm.
Annual brome	*Bromus tectorum* L.
Annual fescue	*Festuca octoflora* Walt.
Arizona cypress	*Cupressus arizonica* Greene.
Aspen	*Populus tremuloides* Michx.
Balsam fir	*Abies balsamea* (L.) Mill.
Balsam-root	*Balsamorrhiza sagittata* (Pursh) Nutt.
Barrel cactus	*Ferocactus acanthoides* (Lemaire) Britton and Rose.
Basket oak	*Quercus prinus* L.
Bear grass	*Nolina microcarpa* S. Wats.
Beech	*Fagus grandifolia* Ehrh.
Beggar's tick	*Lappula occidentalis* (S. Wats.) Greene.
Big rabbit brush	*Chrysothamnus nauseosus* (Pursh) Britton.
Bitterbrush	*Purshia tridentata* (Pursh) DC.
Bitternut	*Hickoria cordiformis* (Wang.) Britton.
Black brush	*Flourensia cernua* DC.
Black cherry	*Prunus serotina* Ehrh.
Black grama	*Bouteloua eriopoda* (Torr.) Torr.
Black gum	*Nyssa sylvatica* Marsh.
Black jack oak	*Quercus marilandica* Muench.
Black spruce	*Picea mariana* (Mill.) B. S. P.
Black walnut	*Juglans nigra* L.
Blue joint grass	*Calamagrostis canadensis* (Michx.) Beauv.
Bluestem	*Andropogon furcatus* Muhl.
Box elder	*Acer negundo* L.
Bristle-cone pine	*Pinus aristata* Engelm.
Broom sedge	*Andropogon glomeratus* (Walt.) B. S. P.
Broom sedge	*Andropogon saccharoides* Swartz.
Bunch grass	*Andropogon scoparius* Michx.
Bud sage	*Artemisia spinescens* D. C. Eaton.
Buffalo grass	*Bulbilis dactyloides* (Nutt.) Raf.
Bur clover	*Medicago hispida* Gaertn.
Bur sage	*Franseria dumosa* A. Gray.
Bur sage	*Franseria deltoidea* Torr.
Bush morning-glory	*Ipomoea leptophylla* Torr.
California needle grass	*Stipa pulchra* Hitchc.
California poa	*Poa scabrella* (Thurb.) Benth.
California poppy	*Eschscholtzia californica* Cham.
California sagebrush	*Artemisia californica* Less.
California scrub oak	*Quercus dumosa* Nutt.
Cane cactus	*Opuntia arborescens* Engelm.
Cat's claw	*Acacia greggii* A. Gray.
Cat tail	*Typha latifolia* L.
Chamiso	*Atriplex canescens* (Pursh) Nutt.
Chestnut	*Castanea dentata* (Marsh.) Borkh.
Chestnut oak	*Quercus montana* Willd.
Cholla	*Opuntia bigelovii* Engelm.
Cholla	*Opuntia echinocarpa* Engelm. & Bigel.
Cholla	*Opuntia acanthocarpa* Engelm. & Bigel.
Cholla	*Opuntia fulgida* Engelm.
Cholla	*Opuntia spinosior* (Engelm. and Bigel.) Toumey.
Coleogyne	*Coleogyne ramosissima* Torr.
Cork-bark fir	*Abies arizonica* Merriam.
Cottonwood	*Populus balsamifera* Linn.
Creosote bush	*Covillea tridentata* (Moc. & Sesse) Vail.
Crowfoot grama	*Bouteloua rothrockii* Vasey.
Curly mesquite	*Hilaria belangerii* Steud.
Desert plantain	*Plantago erecta* Morris.
Desert saltbush	*Atriplex polycarpa* S. Wats.
Douglas fir	*Pseudotsuga macronata* (Raf.) Sudw.
Emory oak	*Quercus emoryi* Torr.
Encelia	*Encelia farinosa* A. Gray.
Engelmann spruce	*Picea engelmanni* Engelm.
False needle grass	*Scleropogon brevifolius* Phil.
Filaree	*Erodium cicutarium* (L.) L'Hér.
Foxtail	*Hordeum murinum* L.
Galleta grass	*Hilaria jamesii* (Torr.) Benth.
Giant cactus	*Carnegiea gigantea* (Engelm.) Britton and Rose.
Grama grass	*Bouteloua gracilis* (H. B. K.) Lag.
Greasewood	*Sarcobatus vermiculatus* (Hook.) Torr.
Ground daisy	*Townsendia exscapa* (Richards.) Porter.
Gum weed	*Grindelia squarrosa* (Pursh) Dunal.
Hemlock	*Tsuga canadensis* (L.) Carr.
Highland live oak	*Quercus wislizeni* A. DC.
Holly-leaf cherry	*Prunus ilicifolia* (Nutt.) Walp.
Honey locust	*Gleditsia triacanthos* L.
Hop sage	*Grayia spinosa* (Hook.) Moq.
Horseweed	*Erigeron canadense* L.
Incense cedar	*Libocedrus decurrens* Torr.
Indian grass	*Sorghastrum nutans* (L.) Nash.
Indian rice	*Zizania aquatica* L.
Indian rice	*Zizania palustris* L.
Jack pine	*Pinus banksiana* Lamb.
Jeffrey pine	*Pinus jeffreyi* "Oreg. Com."
Joshua tree	*Clistoyucca brevifolia* (Engelm.) Rydb.
June grass	*Koeleria cristata* (L.) Pers.
Lechuguilla	*Agave lechuguilla* Torr.
Live oak	*Quercus agrifolia* Née.
Little bunch grass	*Festuca idahoensis* Elmer.
Little rabbit brush	*Chrysothamnus stenophyllus* (A. Gray) Greene.
Loblolly pine	*Pinus taeda* L.
Lodgepole pine	*Pinus contorta* Loud.
Longleaf pine	*Pinus palustris* Mill.
Lowland white fir	*Abies grandis* Lindl.
Mangrove	*Rhizophora mangle* L.
Manzanita	*Arctostaphylos glauca* Lindl.
Marsh grass	*Spartina alterniflora glabra* (Muhl.) Fernald.
Marsh grass	*Spartina patens* (Ait.) Muhl.
Match weed	*Gutierrezia sarothrae* (Pursh) Britton & Rusby.
Mesquite	*Prosopis juliflora* (Swartz) DC.
Mexican piñon	*Pinus cembroides* Zucc.
Mockernut	*Hicoria alba* (L.) Britton.
Mohave yucca	*Yucca mohavensis* Sargent.
Mountain mahogany	*Cercocarpus parvifolius* Nutt.
Mountain sage	*Artemisia frigida* Willd.
Muhlenbergia	*Muhlenbergia gracillima* Torr.
Narrow-leaf saltbush	*Atriplex linearis* S. Wats.
Needle grass	*Stipa spartea* Trin.
Nigger wool	*Carex filifolia* Nutt.
Noble fir	*Abies nobilis* Lindl.
Northern white cedar	*Thuya assingialia* L.
Norway pine	*Pinus resinosa* Ait.
Ocotillo	*Fouquieria splendens* Engelm.
One-seeded juniper	*Juniperus monosperma* (Engelm.) Sarg.
Overcup oak	*Quercus lyrata* Walt.
Painted brush	*Castilleja occidentalis* Torr.
Palo verde	*Cercidium torreyanum* (S. Wats.) Sarg.
Paper birch	*Betula papyrifera* Marsh.
Pasque flower	*Pulsatilla hirsutissima* (Pursh) Britton.
Pennyroyal	*Hedeoma hispida* Pursh.
Phlox	*Phlox hoodii* Richards.
Pickleweed	*Allenrolfea occidentalis* (S. Wats.) Kuntze.
Pignut	*Hicoria glabra* (Mill.) Britton.
Piñon	*Pinus edulis* Engelm.
Pitch pine	*Pinus rigida* Mill.
Plains plantain	*Plantago purshii* Roem. & Schult.
Poa	*Poa sandbergii* Vasey.
Polygonum	*Polygonum bistortoides* Pursh.
Pond pine	*Pinus serotina* Michx.
Post oak	*Quercus stellata* Wangen.
Prickly pear	*Opuntia lindheimeri* Engelm.
Psoralea	*Psoralea tenuiflora* Pursh.
Purple cone-flower	*Echinacea angustifolia* DC.
Rabbit brush	*Chrysothamnus graveolens* (Nutt.) Greene.
Rayless goldenrod	*Isocoma coronopifolia* (A. Gray) Greene.
Red bay	*Persea borbonia* (L.) Spreng.
Red brome	*Bromus rubens* L.
Red fir	*Abies magnifica* Murr.
Red gum	*Liquidambar styraciflua* L.
Red maple	*Acer rubrum* L.
Red oak	*Quercus borealis maxima* (Marsh.) Ashe.
Red samphire	*Salicornia rubra* A. Nels.
Red spruce	*Picea rubens* Sarg.
Reed canary grass	*Phalaris arundinacea* L.
River birch	*Betula nigra* L.
Rock sedge	*Carex rupestris* All.
Rocky Mountain red cedar	*Juniperus scopulorum* Sarg.
Rocky Mountain scrub oak	*Quercus undulata* Torr.
Sacaton	*Sporobolus wrightii* Munro.
Sagebrush	*Artemisia tridentata* Nutt.
Salt grass	*Distichlis spicata* (L.) Greene.
Salt sage	*Atriplex corrugata* S. Wats.
Salt sage	*Atriplex nuttallii* S. Wats.
Samphire	*Salicornia ambigua* Michx.
Sand grass	*Calamovilfa longifolia* (Hook.) Hack.
Sand sage	*Artemisia filifolia* Torr.
Sand sporobolus	*Sporobolus cryptandrus* (Torr.) Gray.
Sawgrass	*Cladium jamaicense* Crantz.
Scabland sage	*Artemisia rigida* A. Gray.
Scrub or Gambel oak	*Quercus gambelii* Nutt.
Scrub pine	*Pinus virginiana* Mill.
Seepweed	*Dondia torreyana* (S. Wats.) Standley.
Serviceberry	*Amelanchier alnifolia* Nutt.
Shadscale	*Atriplex confertifolia* (Torr.) D. Wats.
Shin oak	*Quercus havardii* Rydb.
Shortleaf pine	*Pinus echinata* Mill.
Silver fir	*Abies amabilis* (Loud.) Forb.
Silver maple	*Acer saccharinum* L.
Silvery psoralea	*Psoralea argophylla* Pursh.
Single-leaf piñon	*Pinus monophylla* Torr. & Frem.
Sitka spruce	*Picea sitchensis* (Bong.) Trautv. & Meyer.
Six-weeks grama	*Bouteloua aristidoides* (H. B. K.) Griseb.
Six-weeks needle grass	*Aristida adscensionis* L.
Slash pine	*Pinus caribaea* Morelet.
Slender wheat grass	*Agropyron tenerum* Vasey.
Slough grass	*Spartina michauxiana* Hitchc.
Small sage	*Artemisia nova* A. Nels.
Soapweed	*Yucca glauca* Nutt.
Soft chess	*Bromus hordeaceus* L.
Sotol	*Dasylirion texanum* Scheele.
Sugar maple	*Acer saccharum* Marsh.
Sugar pine	*Pinus lambertiana* Dougl.
Sumac	*Rhus laurina* Nutt.
Sycamore	*Platanus occidentalis* L.
Switch grass	*Panicum virgatum* L.
Tamarack	*Larix laricina* (Du Roi) Koch.
Tasajillo	*Opuntia leptocaulis* DC.
Tobosa grass	*Hilaria mutica* (Buckl.) Benth.
Tule	*Scirpus validus* Vahl.
Tupelo gum	*Nyssa aquatica* L.
Tussock grass	*Sporobolus airoides* Torr.
Utah juniper	*Juniperus utahensis* (Engelm.) Lemmon.
Utah samphire	*Salicornia utahensis* Tidestrom.
Valley oak	*Quercus lobata* Née.
Viznaga	*Ferocactus wislizeni* (Engelm.) Britton & Rose.
Water ash	*Fraxinus caroliniana* Mill.
Water grass	*Paspalum* sp.
Water oak	*Quercus nigra* L.
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
Western larch	*Larix occidentalis* Nutt.
Western needle grass	*Stipa comata* Trin. & Rupr.
Western red cedar	*Thuja plicata* Don.
Western wheat grass	*Agropyron smithii* Rydb.
Western white pine	*Pinus monticola* Dougl.
Western yellow pine	*Pinus ponderosa* Laws.
Wheat grass	*Agropyron spicatum* (Pursh) Scribn. & Smith.
White-bark pine	*Pinus albicaulis* Engelm.
White bay	*Magnolia virginiana* L.
White elm	*Ulmus americana* L.
White fir	*Abies concolor* (Gord.) Parry.
White mountain lily	*Leucocrinum montanum* Nutt.
White pine	*Pinus strobus* L.
White sage	*Kochia americana vestita* S. Wats.
White spruce	*Picea glauca* (Moench) Voss.
Wild buckwheat	*Eriogonum fasciculatum* Benth.
Wild lilac	*Ceanothus hirsutus* Nutt.
Wild oat	*Avena barbata* Brot.
Wild oat	*Avena fatua* L.
Wild onion	*Allium textile* Nels. & Macbr.
Wild rye	*Elymus condensatus* Presl.
Winter fat	*Eurotia lanata* (Pursh) Moq.
Wire-grass	*Aristida longiseta* Steud.
Yarrow	*Achillea millefolium* L.
Yellow birch	*Betula lutea* Michx. f.
Yellow oak	*Quercus velutina* Lam.
Yellow poplar	*Liriodendron tulipifera* L.
Yucca	*Yucca elata* Engelm.

Common names have little more than local significance; the same plant may be known by many different names, and the same name applied to many different plants. We have attempted to use the names applied in the sections in which these plants occur. Other equally good names could have been used. The word "sage" is generally applied in the desert region to any plant with light-colored foliage. Sage and sagebrush are often used for plants which should more properly be called saltbush.

SELECTED REFERENCES.

Allen, E. T.: The western hemlock. U. S. Dept. Agr., Bur. Forestry, Bul. 33, 55 p., 5 fig., 12 pl. Washington, 1902.

Ashe, W. W.: Loblolly or North Carolina pine. N. C. Geol. and Econ. Survey, Bul. 24, 176 p., 27 pl. Raleigh, 1915.

Ayres, H. B., and Ashe, W. W.: The southern Appalachian forests. U. S. Geol. Survey, Prof. Paper 37, 291 p., 37 pl. (2 maps). Washington, 1905.

Bailey, Vernon: Biological survey of Texas. Life zones, with characteristic species of mammals, birds, reptiles, and plants . . . U. S. Dept. Agr., Bur. Biol. Survey, No. Amer. Fauna 25, 222 p., 24 fig., 16 pl., maps. Washington, 1905.

Life zones and crop zones of New Mexico. U. S. Dept. Agr., Bur. Biol. Survey, No. Amer. Fauna 35, 100 p., 6 fig., 16 pl., map. Bibliography, p. 75–82. Washington, 1913.

Baker, H. P.: Native and planted timber of Iowa. U. S. Dept. Agr., Forest Serv., Circ. 154, 24 p. Washington, 1908.

Bentley, H. L.: A Report upon the grasses and forage plants of central Texas. U. S. Dept. Agr., Div. Agros., Bull. 10. 38 p., illus. Washington, 1898.

Bessey, C. E.: The forests and forest trees of Nebraska. Ann. Rpt. Nebr. State Bd. Agr. 1899, p. 79–102. Lincoln, 1900.

Boisen, A. T., and Newlin, J. A.: The commercial hickories. U. S. Dept. Agr., Forest Serv., Bul. 80, 64 p., 17 fig., 6 pl. Washington, 1910.

Bray, W. L.: Forest resources of Texas. U. S. Dept. Agr., Bur. Forestry, Bul. 47, 71 p., 8 pl., 3 maps. Washington, 1904.

The timber of the Edwards plateau of Texas. U. S. Dept. Agr., Bur. Forestry, Bul. 49, 30 p., 5 pl., map. Washington, 1904.

Distribution and adaptation of the vegetation of Texas. Bul. Univ. Texas 82 (Sci. Ser. 10), 108 p., pl., maps. Bibliography, p. 107–108. Austin, 1906.

The development of the vegetation of New York State. Tech. Pub. 3, N. Y. State Col. Forestry, 186 p., 52 fig., 1 fold. map. Bibliography, p. 8. Syracuse, 1915.
Also published as Syracuse Univ. Bul., v. 16, no. 2.

Brendel, Frederick: Flora peoriana; the vegetation in the climate of middle Illinois . . . 89 p. Peoria, 1887.

Buhler, E. O.: Report of soil and timber reconnaissance. Minn. Forestry Bd. 3d Ann. Rept. State Forester, 1913, p. 120–135, illus., 2 maps. St. Paul, 1913.

Burtt-Davy, Joseph: Notes on the flora of Honey Lake Valley. Erythea, v. 6, no. 1, p. 1–11. Berkeley, Calif., 1898.

Card, F W.: The forests of Rhode Island. R. I. Agr. Exp. Sta., Bul. 88, p. 11–39, 25 fig. Kingston, 1902.

Cary, Merritt: A biological survey of Colorado. U. S. Dept. Agr., Bur. Biol. Survey, No. Amer. Fauna 33, 256 p., 39 fig., 12 pl., map. Washington, 1911.

Life zone investigations in Wyoming. U. S. Dept. Agr., Bur. Biol. Survey, No. Amer. Fauna 42, 95 p., 17 fig., 15 pl., map. Washington, 1917.

Chamberlain, T. C.: Geology of eastern Wisconsin. Geol. Wis. Surv 1873–1877, vol. 2, pt. II, p. 91–405, 48 fig., 13 pl. Madison, 1878.

Clements, F. E.: Plant succession; an analysis of the development of vegetation. 512 p., illus., pl. (1 fold.) Bibliography, p. 473–498. Carnegie Inst., Washington, Pub. 242. Washington, 1916.

Plant indicators. 388 p., 25 fig., 92 pl. Carnegie Inst., Washington, Pub. 290. Bibliography, p. 364–373. Washington, 1920.

Cooper, J. G.: On the distribution of the forests and trees of North America . . . Ann. Rept. Smithsn. Inst. 1858, p. 246–280, map. List of principal authorities, p. 248–249. Washington, 1859.

Cowles, H. C.: The physiographic ecology of Chicago and vicinity; a study of the origin, development, and classification of plant societies. Bot. Gaz., vol. 31, no. 2, p. 73–108, fig. 1–18; no. 3, p. 145–182, fig. 19–35. Chicago, 1901.

Dana, S. T.: Paper birch in the Northeast. U. S. Dept. Agr., Forest Serv., Circ. 163, 37 p., 2 fig. 1 map. Washington, 1909.

Dunston, C. E.: Preliminary examination of the forest conditions of Mississippi. Miss. State Geol. Survey, Bul. 7, 76 p., map. Jackson, 1910.

Foster, J. H.: Forest conditions in Louisiana. U. S. Dept. Agr., Forest Serv., Bul. 114, 39 p., 3 fig., 3 pl. Washington, 1912.

Foster, J. H., and Ingall, O. D.: Forest conditions on the Allegheny and Monongahela basins. Rpt. Flood Com., Pittsburgh, App. 1, p. 1–37, map. Pittsburgh, 1912.

—— **Krausz, H. B., and Johnson, G. W.**: Forest resources of eastern Texas. Bull. Agr. and Mech. Col., Texas, s. 3, vol. 3, no. 10 (Bull. 5, Dept. Forestry), 57 p., lilus., 2 maps. College Station, 1917.

Frémont, J. C.: Report of the exploring expedition to the Rocky Mountains in the year 1842, and to Oregon and north California in the years 1843–44 . . . 583 p., pl., maps. U. S., 28th Cong., 2d sess., House Ex. Doc. 166. Washington, 1845.

Frothingham, E. H.: The northern hardwood forest: its composition, growth, and management. U. S. Dept. Agr., Bull. 285, 80 p., 15 pl. Washington, 1915.

Fuller, G. D.: Evaporation and soil moisture in relation to the succession of plant associations. Bot. Gaz., vol. 58, no. 3, p. 193–234, 27 fig. Literature cited, p. 233–234. Chicago, 1914.

Gannett, Henry: The forests of Oregon. U. S. Geol. Survey, Prof. Paper 4, 36 p., 7 pl. (1 map). Washington, 1902.

The forests of Washington, a revision of estimates. U. S. Geol. Survey, Prof. Paper 5, 38 p., map. Washington, 1902.

Gerhard, Fred: Illinois as it is. Chicago, 1857.

Geyer, C. A.: Notes on the vegetation and general character of the Missouri and Oregon territories, made during a botanical journey from the State of Missouri, across the south-pass of the Rocky Mountains, to the Pacific, during the years 1843 and 1844. *In* Lond. Jour. Bot., vol. 4, p. 479–492, 653–662; vol. 5, p. 22–41, 198–208, 285–310, 509–524. 1845–46.

Griffiths, David: Range improvement in Arizona. (Coöperative experiments with the Arizona experiment station.) U. S. Dept. Agr., Bur. Plant Indus., Bul. 4, 31 p., 6 pl. Washington, 1901.

Forage conditions on the northern border of the Great Basin, being a report upon investigations made during July and August, 1901, in the region between Winnemucca, Nevada, and Ontario, Oregon. U. S. Dept. Agr., Bur. Plant Indus., Bul. 15, 60 p., 16 pl., map. Washington, 1902.

The grama grasses; Bouteloua and related genera. *In* Contrib. U. S. Nat. Herb., vol. 14, pt. 3, p. 343–428, fig. 19–63, pl. 67–83. Washington, 1912.

Hall, Elihu: Notes on some features of the flora of eastern Kansas. Amer. Journ. Sci., s. 2, vol. 50, no. 148, p. 29–35. New Haven, Conn., 1870.

Hall, H. M.: A botanical survey of San Jacinto Mountain. Univ. Calif. Pub. Bot., v. 1, 139 p., illus., 14 pl. (2 maps). Berkeley, 1902.

Hall, R. C.: Preliminary study of forest conditions in Tennessee. Tenn. State Geol. Survey Bul. 10–A, 56 p., pl. Nashville, 1910.

Forest conditions in Kentucky and Tennessee. *In* Amer. Forestry, vol. 19, no. 8, p. 533–543, illus. Washington, 1913.

—— **and Ingall, O. D.**: Forest conditions in Illinois. Ill. State Lab. Nat. Hist., Bul. vol. 9, art. 4, p. 175–253, pl. 21–36. Bibliography, p. 250–253. Urbana, 1911.

Harper, R. M.: Georgia's forest resources. South. Woodlands, v. 1, no. 3, p. 4–23; no. 4, p. 1–19, illus., maps; no. 5, p. 3–19, maps, 1907; no. 6, p. 15–32, maps, 1908. Athens, Ga., 1907–1908.

Vegetation types [of an area in central Florida]. *In* Fla. State Geol. Surv., 7th Ann. Rept., [1913–14], p. 135–188, fig. 54–70, map. Tallahassee, 1915.
Data for map secured by Herman Gunter, Emil Gunter, C. N. Mooney, and W. J. Latimer.

A forest census of Alabama by geographical divisions. Proc. Soc. Amer. Foresters, vol. 11, no. 2, p. 208–214, map. Washington, 1916.

Harshberger, J. W.: The vegetation of the salt marshes and of the salt and fresh water ponds of northern coastal New Jersey. Proc. Acad. Nat. Sci., vol. 61, pt. 2, p. 373–400, 6 fig. Philadelphia, 1909.

Phytogeographic survey of North America . . . 790 p., illus., 18 pl., fold. map. Bibliography, p. 46–92. Leipzig, New York, 1911.
(Die vegetation der erde hrsg. von A. Engler und O. Drude, xiii.)

The vegetation of south Florida south of 27° 30′ north, exclusive of the Florida Keys. Trans. Wagner Free Inst. Sci., vol. 7, pt. 3, p. 51–189, 2 fig., 10 pl., map. Philadelphia, 1914.

The vegetation of the New Jersey pine-barrens; an ecologic investigation. 329 p., illus., fold. pl., map. Philadelphia, 1916.

Hawley, R. C., and Hawes, A. F.: Forestry in New England . . . ed. 1, 479 p., illus., 2 fold. maps. Bibliography, p. 420–425. New York, 1912.

Hilgard, E. W.: Report on the geology and agriculture of the State of Mississippi, 391 p., 3 pl., map. Jackson, 1860.

Holmes, J. S.: Forest conditions in western North Carolina. N. C. Geol. and Econ. Survey, Bul. 23, 116 p., 8 pl. (1 map). Raleigh, 1911.

—— **and Foster, J. H.**: A study of forest conditions of southwestern Mississippi . . . Miss. State Geol. Survey, Bul. 5, 56 p., map. Jackson, 1909.

Ives, J. C.: Memoir to accompany a military map of the peninsula of Florida, south of Tampa Bay . . . 42 p., 2 maps. New York, 1856.

Jepson, W. L.: A flora of California. pt. 1–7, illus., pl. Berkeley, 1909–1922.

A flora of western middle California. ed. 2, 515 p. San Francisco [1911].

Kearney, T. H., Briggs, L. J., Shantz, H. L., McLane, J. W., and Piemeisel, R. L.: Indicator significance of vegetation in Tooele Valley, Utah. Journ. Agr. Research, v. 1, no. 5, p. 365–417, 13 fig., pl. 42–48. Washington, 1914.

Kellogg, R. S.: Forest belts of western Kansas and Nebraska. U. S. Dept. Agr., Forest Serv., Bul. 66, 44 p., 6 pl., map. Washington, 1905.

Kennedy, P. B., and Doten, S. B.: A preliminary report on the summer ranges of western Nevada sheep. Nev. Agr. Exp. Sta., Bul. 51, 57 p., 26 pl., map. Reno, 1901.

Kentucky, Bureau of Agriculture, Labor and Statistics: Study of forest conditions in Kentucky. Report 1–3, Louisville and Frankfort, 1907–09.

Langille, H. D.; Plummer, F. G.; Dodwell, Arthur; Rixon, T. F.; Leiberg, J. B., and Gannett, Henry: Forest conditions in the Cascade Range forest reserve, Oregon. U. S. Geol. Survey, Prof. Paper 9, 298 p., 41 pl. (3 maps). Washington, 1903.

Lapham, I. A.: Wisconsin: its geography and topography, history, geology, and mineralogy . . . ed. 2, 208 p. Milwaukee, New York, 1846.

Leiberg, J. B.: Forest conditions in the northern Sierra Nevada, California. U. S. Geol. Survey, Prof. Paper 8, 194 p., 12 pl. (maps). Washington, 1902.

Livingston, B. E., and Shreve, Forrest: The distribution of vegetation in the United States, as related to climatic conditions. Literature cited, p. 587–590. Carnegie Inst. of Washington, Pub. 284, 590 p., 74 fig., 73 pl. Washington, 1921.

Lyford, C. A.: Forest conditions in southern New Hampshire. N. H. Forestry Com. Bien. Rpt., 1905–06, p. 161–276, 19 pl. Concord, 1907.

Mason, D. T.: The life history of lodgepole pine in the Rocky Mountains. U. S. Dept. Agr., Bul. 154, 35 p., 5 pl. Washington, 1915.

Mattoon, W. R.: Life history of shortleaf pine. U. S. Dept. Agr., Bul. 244, 46 p., 12 fig., 10 pl. Washington, 1915.

The southern cypress. U. S. Dept. Agr., Bul. 272, 74 p., 7 fig., 12 pl. Washington, 1915.

Mayr, Heinrich: Die Waldungen von Nordamerika . . . 448 p., illus., 13 pl. (1 fold.) incl. map. München, 1890.

Merriam, C. H.: Life zones and crop zones of the United States. U. S. Dept. Agr., Div. Biol. Surv., Bul. 10, 79 p., map. Washington, 1898.

Mohr, Charles: Notes on the red cedar. U. S. Dept. Agr., Div. Forestry, Bul. 31, 37 p., 12 fig., 3 pl. Washington, 1901.

Plant life of Alabama . . . Contrib. U. S. Nat. Herb., vol. 6, 921 p., 13 pl. Washington, 1901.
Reprinted by Alabama Geological Survey, Tuscaloosa, 1901.

Moore, W. M.: Forest conditions in South Carolina. Report of preliminary examination and survey. S. C. State Dept. Agr., Bul. 1, 54 p., illus., maps. Columbia, 1910.

Munger, T. T.: The growth and management of Douglas fir in the Pacific Northwest. U. S. Dept. Agr., Forest Serv., Circ. 175, 27 p., 4 fig. Washington, 1911.

Nuttall, Thomas: A journal of travels into the Arkansas territory during the year 1819. 296 p., 5 pl., fold. map. Philadelphia, 1821.

Pammel, L. H.: A comparative study of the vegetation of swamp, clay, and sandstone areas in western Wisconsin, southeastern Minnesota, northeastern, central, and southeastern Iowa. Proc. Davenport Acad. Sci., v. 10, 1904–05, p. 32–126, 42 fig. (incl. maps). 1905.

Bibliography, p. 34. Reprinted as Contrib. Bot. Dept., Iowa State Col. Agr., 28. Ames, 1905.

Parish, S. B.: Plant ecology and floristics of Salton sink. *In* Macdougal, D. T. The Salton Sea . . . p. 85–114. (Carnegie Inst., Washington, Pub., 193.) Washington, 1914.

Plummer, F. G.: Forest conditions in the Cascade range, Washington, between the Washington and Mount Rainier forest reserves. U. S. Geol. Survey, Prof. Paper 6, 42 p., 11 pl. (6 maps). Washington, 1902.

Chaparral: studies in the dwarf forests, or elfin-wood, of southern California. U. S. Dept. Agr., Forest Serv., Bul. 85, 48 p., 7 fig., 8 pl. (1 map). Washington, 1911.

Pool, R. J.: A study of the vegetation of the sandhills of Nebraska. Minn. Bot. Studies, vol. 4, pt. 3, p. 189–312, 16 fig., pl. 26–40, map. Minneapolis, 1914.

Literature cited, p. 308–312.

Pound, Roscoe, and Clements, F. E.: Phytogeography of Nebraska. I. General survey. Univ. Nebr., Bot. Survey Nebr., no. 8, 442 p., 4 maps. Bibliography, p. 22–30. Lincoln, 1900.

Record, S. J.: Forest conditions of the Ozark region of Missouri. Mo. Agr. Exp. Sta., Bul. 89, p. 195–280, 6 fig., map. Columbia, 1910.

Rixon, T. F.: Forest conditions in the Gila River forest reserve, New Mexico. U. S. Geol. Survey, Prof. Paper 39, 89 p., 2 pl. (1 map). Washington, 1905.

Robbins, W. W.: Native vegetation and climate of Colorado in their relation to agriculture. Colo. Agr. Exp. Sta., Bul. 224, 56 p., 20 fig. Ft. Collins, 1917.

Roth, Filibert, and Fernow, B. E.: Forestry conditions and interests of Wisconsin, with a discussion by B. E. Fernow. U. S. Dept. Agr., Forest Serv., Bul. 16, 76 p., map. Washington, 1898.

Sampson, A. W.: Natural revegetation of range lands based upon growth requirements and life history of the vegetation. Journ. Agr. Research, vol. 3, no. 2, p. 93–148, 6 fig., pl. 12–23. Washington, 1914.

Sampson, H. C.: An ecological survey of the prairie vegetation of Illinois. Bul. Ill. Nat. Hist. Survey, 1921. v. 13, p. 523–577, pl. 48–77, 2 maps. Urbana, 1921.

Sargent, C. S.: Report on the forests of North America (exclusive of Mexico). U. S. Census Off., 10th Census, 1880, v. 9, 612 p., 39 maps. Washington, 1884.

Sarvis, J. T.: Composition and density of the native vegetation in the vicinity of the northern Great Plains field station. In Journ. Agr. Research, 1–19, p. 63–72, pl. 12–14. Washington, 1920.

Shaler, N. S.: Forests of North America. Scribner's Mag., v. 1, no. 5, p. 561–580, illus. New York, 1887.

Shantz, H. L.: Natural vegetation as an indicator of the capabilities of land for crop production in the Great Plains area. U. S. Dept. Agr., Bur. Plant Indus., Bul. 201, 100 p., 23 fig., 6 pl. Washington, 1911.

The natural vegetation of the Great Plains Region. *In* Ann. Assoc. Amer. Geogr., vol. 13, no. 2, p. 81–107, pl. 3–8, map. Albany, 1923.

Shimek, B.: The distribution of forest trees in Iowa. *In* Proc. Iowa Acad. Sci., vol. 7, 1899, p. 47–59, pl. 4. Des Moines, 1900.

The prairies. Bul. Lab. Nat. Hist., State Univ. Iowa, vol. 6, no. 2, p. 169–240, 14 pl. (1 map). Bibliography, p. 231–240. Iowa City, 1911.

Shreve, Forrest: The vegetation of a desert mountain range as conditioned by climatic factors. 112 p., 36 pl., map. (Carnegie Inst., Washington, Pub. 217.) Washington, 1915.

A map of the vegetation of the United States. Geogr. Rev., vol. 3, no. 2, p. 119–125, map. New York, 1917.

Smith, J. G.: Forage conditions of the prairie region. U. S. Dept. Agr. Yearbook, 1895, p. 301–324, fig. 70–74. Washington, 1896.

Sterrett, W. D.: Scrub pine. U. S. Dept. Agr., Forest Serv., Bul. 94, 27 p., pl. Washington, 1911.

Sterrett, W. D.: The ashes: their characteristics and management. U. S. Dept. Agr., Bul. 299, 88 p., 16 pl. (2 maps). Washington, 1915.

Sudworth, G. B.: Forest atlas. Geographic distribution of North American trees. pt. 1, maps (partly col.) U. S. Dept. Agr., Forest Service. Washington, 1913.

Swallow, G. C.: Geological report of the country along the line of the southwestern branch of the Pacific Railroad of Missouri. 93 p., map. St. Louis, 1859.

Thornber, J. J.: The prairie-grass formation in region I. Univ. Nebr. Bot. Survey Nebr., no. 5, p. 19–143, pl., map. Lincoln, 1901.

The grazing ranges of Arizona. Ariz. Agr. Exp. Sta., Bul. 65, p. 245–360, 5 fig., 12 pl., map. Tucson, 1910.

Tracy, S. M.: A report upon the forage plants and forage resources of the Gulf States. U. S. Dept. Agr., Div. Agros., Bul. 15, 55 p., 20 fig. Washington, 1898.

U. S. Department of Agriculture, Forestry Division: Report on the forest conditions of the Rocky Mountains, and other papers . . . U. S. Dept. Agr., Forestry Div., Bul. 2, 252 p., fold. map. Nine papers by different authors. Washington, 1888.

U. S. Department of Agriculture, Bureau of Soils: Field operations, 1899–1913 [Reports 1–15]. Maps to accompany each report. Washington, 1900–1916.

Later reports are issued by counties in the form of advance sheets pending publication of annual reports.

U. S. Geological Survey: Annual reports 19–21, 1897–1900, pt. 5, Forest reserves. Washington, 1899–1900.

U. S. War Department: Reports of explorations and surveys, to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean, 1853–1856. 12 vol. in 13, illus. Washington, 1855–1860.

Vestal, A. G.: A black-soil prairie station in northeastern Illinois. Bul. Torrey Bot. Club, vol. 41, no. 7, p. 351–363, 7 fig. Lancaster, Pa., 1914.

Watson, Sereno, and others: Botany. 525 p., 40 pl., 1 map. (Rpt. [U. S.] Geol. Expl. 40th Parallel, v. 5). Washington, 1871.

Weaver, J. E.: A study of the vegetation of southeastern Washington and adjacent Idaho. Univ. Studies, Univ. Nebr., vol. 17, no. 1, 131 p., 48 fig. Literature cited, p. 113–114. Lincoln, 1917.

West Virginia Geological Survey. Map of West Virginia showing virgin and cut-over forest areas . . . fold. Baltimore, [1911?].

Whitford, H. N.: The genetic development of the forests of northern Michigan; a study in physiographic ecology. Bot. Gaz., vol. 31, no. 5, p. 289–325, 18 fig. Chicago, 1901.

Wilcox, E. V.: The grazing industry. Hawaii Agr. Exp. Sta. 91 p., Bul. Honolulu, 1911.

Williamson, A. W.: Cottonwood in the Mississippi valley. U. S. Dept. Agr., Bul. 24, 62 p., illus., 6 pl. Washington, 1913.

Woolsey, T. S., jr.: Western yellow pine in Arizona and New Mexico. U. S. Dept. Agr., Forest Serv., Bul. 101, 64 p., 11 fig., 4 pl. Washington, 1911.

Woolsey, T. S. jr., and Chapman, H. H.: Norway pine in the lake States. U. S. Dept. Agr., Bul. 139, 42 p., 1 fig., 6 pl. Washington, 1914.

Wooton, E. O., and Standley, P. C.: Carrying capacity of grazing ranges in southern Arizona. U. S. Dept. Agr., Bul. 367, 40 p., 10 pl., maps. Washington, 1916.

Zon, Raphael: Chestnut in southern Maryland. U. S. Dept. Agr., Bur. Forestry, Bul. 53, 31 p., 5 pl. Washington, 1904.

Loblolly pine in eastern Texas, with special reference to the production of cross-ties. U. S. Dept. Agr., Forest Serv., Bul. 64, 53 p., 2 fig., 4 pl. Washington, 1905.

Balsam fir. U. S. Dept. Agr., Bul. 55, 68 p., 8 fig., 2 pl. Bibliography, p. 68. Washington, 1914.

101